

CARRIAGEWAYS and FOOTWAYS

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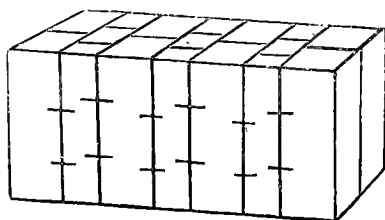
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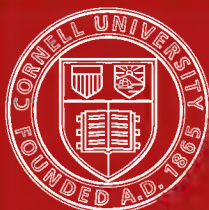


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THE CONSTRUCTION OF CARRIAGEWAYS
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THE CONSTRUCTION

OF

CARRIAGEWAYS & FOOTWAYS

BY

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PREFACE.

ALTHOUGH much has already been written upon the subject of the construction and maintenance of macadamised roads, there is not much literature which deals with the construction of paved streets and footways suitable for towns where there is considerable and heavy traffic. These pages will consequently be devoted to the consideration of the latter subjects, which will be dealt with in as practical and condensed a form as the author's twenty-five years of experience will permit.

The book has been written—at the request of the publishers—during the intervals of a somewhat busy professional career, and makes no pretence to literary merit.

H. P. B.

Liverpool, 1895.

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THE

CONSTRUCTION OF CARRIAGEWAYS AND FOOTWAYS.

PRELIMINARY REMARKS.

Before any determination can be arrived at as to the material to be employed and the method to be adopted in paving the streets of any city or town, the following considerations must be carefully investigated :

- (1) The amount and description of the traffic.
- (2) The gradient, width, and continuity of the streets.
- (3) The class of property which abuts on the streets.
- (4) The local facilities for obtaining a suitable material for a pavement.
- (5) The financial position of the local authority who are responsible for the paving.

Unfortunately, the consideration which the author has placed last very frequently is taken first, under the mistaken idea that the cheapest pavement is the most economical, whereas experience has shown that, so far from this being the case, it is an absolutely proved fact that the pavement most suitable for the

traffic is the cheapest in the end. For instance, in the city of Liverpool, where about twenty-two years ago the Council, acting under the advice of their engineer, introduced the system of paving their streets in the best possible manner with impervious granite sett paving, so that at the present date out of 258 miles of roads ("maintainable by the inhabitants at large") in this city 113 miles are thus paved.

The result of this has been as follows: In the year 1872, when impervious pavements were first introduced, there were about 200 miles of roads, and their annual maintenance cost £38,280, the interest and sinking fund was £15,756, or a total cost of £54,036, making a cost of £270 per mile; whereas in the year 1894, with 258 miles, their annual maintenance only cost £14,205, the interest and sinking fund was £36,917, making a total cost of £51,122 per annum, or £198 per mile.

No doubt many other cities and towns could place on record similar good results arising from the above policy of using only the most suitable and best materials for carriageway pavements, which clearly proves the point which the author desires to emphasise.

The other considerations which have been set forth will be dealt with hereafter in detail in their proper place, and the author will therefore at once proceed to deal with the questions of the amount and description of traffic.

AMOUNT AND DESCRIPTION OF TRAFFIC.

It is evident that a pavement which would be eminently suitable for a heavy commercial traffic would be quite out of place for that of a health resort or of a quiet provincial town, and consequently it is essential that a careful investigation and general census of the traffic is required to be taken before the class of pavement can be decided upon.

It is to be regretted that in most cases where a census of traffic has hitherto been taken, no notice of the approximate *weight* of that traffic has been observed, nor has the width of the street through which the traffic has passed been given. It is absolutely necessary, in order to form a correct judgment of the effect of traffic upon any roadway, that all these particulars should be carefully ascertained and the results reduced to a standard: and this standard, for convenience, may be stated as *tons weight of traffic per yard of width of roadway per annum*.

Where the traffic is of a comparatively light and fast character the average speed may with advantage be added to the other collected facts, as well as possibly in some cases the number of horses, in addition.

In order to assist engineers and others in the preparation of a complete census of traffic the accompanying specimen "Record Table of Street Traffic" for the use of an observer is given. (See Table A.)

With such facts before him, and a perusal of the foregoing table carefully prepared by his assistants, the engineer would be able to form his opinion, based upon ascertained facts, as to the most suitable pavement to be adopted and the behaviour of all roadways under certain fixed conditions: and the present uncertainty as to the durability and suitability of the various descriptions of pavement from which he can choose would be to a great extent removed.

What guide is it to us to know that there were 11,900 vehicles running daily in Cheapside in 1843, or that 14,924 vehicles of various specified descriptions passed along the Strand in 1890, unless the weights and widths between curbs is given us? The author had hoped to be able to extricate some useful information from the statistics that have from time to time been gathered upon this point, but under the existing obscurity of information he found it is impossible, and has to content himself with recording the following somewhat meagre statistics which is all he has been able to prepare from available information.

In Montreal, it appears from an excellent diagram prepared by the city engineer from observed traffic in that city that the following is the maximum amount of traffic upon different descriptions of paving:

Stone blocks	7,500 tons per yard width per annum.
Wood blocks	15,000 „ „ „ „ „
Sicilian asphalte...	12,500 „ „ „ „ „
Trinidad asphalte..	7,800 „ „ „ „ „

The wear or behaviour, however, of the pavements under these conditions is unfortunately not given.

In the city of London, assuming a certain weight per vehicle, the weights and width not being given, nor the locality, Aberdeen granite setts lasted for fifteen years with an assumed traffic of 800,000 tons per yard width per annum.

In Tooley-street, London, which was paved with 4in. by 7in. Guernsey granite setts in 1884 upon a concrete foundation, the setts have worn down in ten years about 1in. under a traffic of 316,084 tons per yard width per annum.

Aberdeen granite setts wore down $1\frac{1}{2}$ in. on Blackfriars Bridge in $13\frac{1}{4}$ years. Guernsey granite wore $\frac{1}{4}$ in. in the same period. (No statement as to amount of traffic.)

Aberdeen granite on London Bridge wears out at the rate of $\cdot222$ of an inch per year with 15,000 vehicles in twelve hours. As it is 33ft. between curbs, this equals 1,364 vehicles per yard of width per day of twelve hours; and assuming three tons per vehicle, it would amount to about 1,280,000 tons per yard width per annum, excluding Sundays.

In the city of Liverpool more careful statistics have been prepared, for when the first impervious pavement in Liverpool was laid in North John-street, in November, 1872, the carriageway was paved in sections from channel to channel with setts from various localities in order to ascertain their behaviour under heavy traffic. It is now over twenty-one years since this pavement was laid, so that a fair comparison may be made of their respective merits. The distributed traffic amounts to 217,000 tons per yard in width of carriageway per annum. One of the sections, consisting of setts from Dalbeattie, having worn down $1\frac{1}{4}$ in. below the adjoining

harder setts, was, after being down five years, taken up and replaced by harder stones. Two sections, with a combined area of 179 yards paved with setts from quarries in the neighbourhood of Ludlow, were found to have worn down so much that doubts were expressed as to the stability of the concrete foundation, which it was suggested had given way and so caused a depression in the surface. In order to settle this an official examination was made on August 24, 1883, when, upon the removal of the paving setts, the foundation was found to be intact and perfectly sound; the setts had, however, worn down 1 in., while the adjoining Carnarvonshire setts showed no perceptible wear. Further examinations were made on February, 20, 1888, and on March, 26, 1888, when the wear was ascertained to be from $1\frac{1}{4}$ in. to $2\frac{1}{4}$ in. below the adjoining pavement. Several fractured setts were removed and replaced by others, and again on November 23, 1889, when a considerable number of the stones were so fractured by the heavy weight of the traffic that the whole section was taken up, and as many of the setts as were fit and less worn were repaved upon a thick layer of gravel to replace the broken and worn setts. An area of $20\frac{3}{4}$ yards was paved with other setts of known durability. When this examination took place, some setts in the adjoining section were taken up and were found to have worn so slightly that the original quarry irregularities on the wearing surface of the stone were still visible, the chief wear being on the edges or arrises.

A further examination of the pavement was made on January 25, 1894, with the results shown in Table B (only the wear and tear of the Carnarvonshire setts

TABLE C.—CITY OF LIVERPOOL. TABLE OF COST OF REPAIRS OF STREETS UNDER ASCERTAINED TRAFFIC.

Name of Street.	Description of Pavement.	Traffic per yard width per annum.	Average Cost of Maintenance per annum for five years.	Area in yards.	Average Cost per square yard per annum.	Present Condition of Pavement.	Gradient.
First street	Macadam	Tons. 69,139	£ s. d. 140 8 11	Sup. yards 1,792	s. d. 1 6-81	Indifferent	1 in 22
Second street	Macadam	110,275	137 18 0	1,837	1 6-01	Indifferent	1 in 18
Third street (paved 1885).	Impervious setts	67,315	Nil.	1,573	Nil.	Very good	1 in 22
Fourth street (paved 1885).	Impervious setts	37,175	Nil.	1,327	Nil.	Very good	1 in 18
Fifth street (paved 1885).	Impervious setts	42,000	Nil.	7,735	Nil.	Perfect	1 in 500
Sixth street (paved 1877).	Impervious setts	149,000	0 3 11	3,414	0 0-013	Very fair	1 in 56
Seventh street (paved 1877)	Henson's wood pavement	100,000*	67 17 3	1,310	1 0-43	Much worn	1 in 56
Eighth street (first paved 1874)	Improved wood pavement	94,000	219 6 8 (a)	4,250	1 0-386	Much worn	1 in 33

* Vehicular traffic not taken, but assumed to be slightly in excess of eighth street.

(a)	Total Expenditure, five years.		Average, five years.	
	£ s. d.		£ s. d.	
	342 17 7		68 11 6	
Contract maintenance, 1889-1890 ...	753 15 7		150 15 2	
City engineer, 1892-1893	—		—	
„ 1889-1890-1891 (nil)	£1,096 13 2		£219 6 8	

being given, the other setts, as will be seen from the previous examinations, being unfit to bear the weight of the heavy traffic carried over this street).

TABLE B.

East Side of Carriageway.	Crown of Carriageway.	West Side of Carriageway.	When Paved.
*A. Wear immeasurable, surface depression still visible.	Wear $\frac{1}{8}$ in. to $\frac{1}{4}$ in., surface depression still visible.	Wear $\frac{1}{2}$ in.	November, 1872.
*B. Wear about $\frac{3}{8}$ in.	Wear about $\frac{3}{8}$ in. on one side of sett.	Wear about $\frac{3}{8}$ in. on one side of sett.	Ditto.
*C. Wear $\frac{1}{4}$ in.	—	Wear about $\frac{3}{8}$ in.	Ditto.

It should be noted that the weights conveyed along the west side of this street northwards are much in excess of those carried along the east side from the north to south, probably to the extent of 33 per cent., so that the distributed traffic does not really represent the weight borne by the pavement on the west side; and this is a point which should be borne in mind in ascertaining the effect of traffic upon pavements where the conditions are exceptional.

The accompanying table of the observed traffic and cost of repairs of certain streets in the city of Liverpool will also be useful. (See Table C.)

* The actual names of the quarries from which these setts came are not given for obvious reasons.

It may also be interesting to note that the average cost of certain pavements in Liverpool for the past four years is as shown in Table D.

TABLE D.

Pavement.	Area, super yards.	Annual Main- tenance.	Maintenance.			
			Per 1,000 sup. yards.		Per sup. yard.	
		£ s. d.	£ s. d.		d.	
Impervious sett	1,723,674	1,754 3 5	1 0 4	25	244	
Wood	17,500	405 10 10	23 3 5	71	5·562	
Old-style sett	418,137	796 14 9	1 18 1	3	457	
Boulders	1,187,826	1,133 12 6	0 19 1	05	229	
Macadam	227,071	2,753 5 2	12 2 6		2·91	
Asphalte or tar macadam	21,724	181 16 4	8 7 4	65	2·009	
Natural asphalte on concrete } (under contract	19,680	152 19 5	7 15 5	5	1·865	

With regard to this table it must be noted that the maintenance of the impervious sett pavement is remarkably low when it is considered that it is carrying a traffic many hundred times more severe than that of the boulder pavement, and that, in addition to this, the repairs executed to the boulder-paved streets are purposely restricted to absolutely necessary repairs, as this description of street is gradually being eliminated.

SELECTION OF PAVING MATERIAL.

The gradient of a street to some extent decides the question of the material to be employed for paving. Asphalte would necessarily be unsuitable for streets of steeper gradient than 1 in 60; wood, 1 in 36; and stone setts, 1 in 16. Mr. Spalding, of the Cornell University, in America, upon this point,* says "the smoother forms of pavements are only applicable to light gradients," and he gives the following: rock asphalte, 1 in 50; Trinidad asphalte, 1 in 25; brick, 1 in 17; wood, "a little steeper"; and "stone blocks are satisfactory to about a 10 per cent. gradient" (1 in 10). But Mr. Spalding has evidently over-estimated safe gradients for wood, as a steeper gradient than 1 in 17 must be undoubtedly bordering on dangerously slippery. The width of a street also has some bearing on the subject of the selection of a paving material—as wood, for instance, is not advisable in a narrow street, where owing to the height of the buildings on each side the light and air are excluded. Continuity of one description of pavement has recently been discussed, and experience has shown that horses and drivers become more used to and confident upon continuous streets of the same paving. It is found that where a horse has to travel for a few yards upon macadam, then upon stone setts, then

* "A Textbook on Roads and Pavements," by Fred P. Spalding, New York.

upon wood, and, lastly, upon asphalte, or any combinations of these pavements, that accidents by falls are more likely to occur. Recent statistics have shown that in the city of Berlin there are half the falls now upon double the area of asphalted streets. The class of property which abuts on a street should also to some extent guide the selection of the paving material. Stone setts may be very suitable for streets of warehouses, but would be inexpedient for residential streets, especially where there might be hospitals, schools, or places of worship. The fact of the greater part of the streets in the West-end of London being verged with shops has been the cause of so much wood pavement having been laid down.

This consideration has led to the introduction of the hardest stone setts in our northern commercial cities, to the wood pavements of the West-end of London, to the asphalte of Berlin and Pesth, and to the park-like gravelled and macadamised roadways of the seaside health resorts which abound on our coasts.

In visiting any town we are as much struck with the good or bad condition and structure of the street surfaces as with the grandeur or otherwise of the buildings with which those streets are surrounded.

With regard to local facilities for obtaining a suitable material wherewith to pave streets, this question, though worthy of some consideration in a few cases, must not carry too much weight. As has already been pointed out, the best and most durable pavement, other considerations being equal, is the most economical in the end.

The following may be taken as the considerations which enter upon this question of economy :

- (a) The first cost and interest, and sinking fund on this cost, which is dependent on the life of the pavement.
- (b) The annual cost of maintenance and repairs.
- (c) The cost of reinstatement after disturbance.*
- (d) The cost of cleansing.
- (e) Incidentally, the effect on vehicles and horses using the roadway.
- (f) The effect upon land values or business interests.

With regard to the effect on vehicles and horses using the roadway, several considerations are opened up. A rough road means wear and tear on vehicles and horses, whereas a good pavement means longer life to both ; and the cost of transportation is greatly affected by the condition of the road over which the traffic is carried both in speed and weight. It is difficult to estimate the value of improved roadway surfaces, but it is notorious that the introduction of good pavements on roads immediately adds to the weights which can be drawn by a horse. The omnibus traffic in the Metropolis and other large centres is an instance of this in one direction, and the enormous loads which may be seen behind the horses dragging the lorries and wagons in a city like Liverpool is another. As to the effect of good pavements upon land values, this cannot be disputed, as there are instances of rents having been raised successfully 20 or 30 per cent. upon a street being improved by a better class of pavement.

* This is no inconsiderable item when we consider the constant disturbances of roadways where there are no subways. In New York the streets were opened 27,000 times for repairs alone in the year 1890.

No artificial test has yet been discovered which can decide the question of the most suitable material to be used for street-paving purposes even as regards durability; chemical analysis, specific gravity, geological formation are no guide, nor are the tests of crushing, rubbing, or absorption. Actual time test under observation of real conditions is the only reliable method, and having thus decided, see that you get the genuine article you have selected. There is very little variation in the value of any stone, for instance; it is the labour of preparation that gives it its value.

Before concluding these remarks, let me set forth the detailed and condensed requirements of a perfect street pavement. Though the ideal is seldom reached, it is what we should all strive after:

- (1) Impermeability.*
- (2) Durability.
- (3) Foothold.
- (4) Ease of traction.
- (5) Adaptability to all gradients.
- (6) Adaptability to all classes of traffic.
- (7) Noiselessness.
- (8) Non-manufacture of mud or dust.
- (9) Ease of cleansing.
- (10) Ease of repairs.
- (11) Economical in first cost and maintenance.
- (12) Not influenced by climatic changes.
- (13) Good appearance.

* This is placed first on sanitary grounds. The importance of impermeable paving in crowded cities cannot be over-estimated. Certain zymotic diseases have been considerably reduced in many cities following the introduction of impervious pavements.

FOUNDATIONS.

The importance of a properly constructed and rigid foundation for all weight-carrying streets cannot be overstated. It is the foundation which carries the weight; the material with which the street is paved is merely the skin or veneer to preserve the real roadway, the foundation underneath. Several methods of constructing this foundation have been adopted from time to time.

One of the earliest, as practised for many years at Manchester, was to excavate the ground to the proper depth and contour and then to dump foundry ashes or clinker upon the ground thus prepared and allow the traffic to consolidate the mass. Upon this foundation so prepared the stone setts were placed and grouted.

In the city of Norwich the author believes that many miles of wood pavement have been laid upon ordinary macadamised roads as a foundation.

Neither of these methods can be recommended, as such a foundation must be unstable, and if disturbed by trenches the sides would collapse. A better foundation than these, but still one that is open to some objections, is that which is known as a hand-pitched or "pinned" foundation, which may be described as follows: After the ground has been prepared to the proper depth and contour, and thoroughly consolidated by rolling or otherwise, pieces of rock about 6in. in depth are set on edge by hand in the manner of a rough pavement. Over this a coating of gravel is laid of sufficient thickness to fill

in the interstices and to form a smooth surface to the foundation, which is then thoroughly consolidated by rolling with a steam-roller, and upon the foundation thus prepared the paving is laid. Fig. 1 is a sketch of a hand-pitched foundation.

Modern experience, however, has shown that the best foundation for all paved roadways is undoubtedly one that is composed of cement concrete. There are two methods for this construction. The first, which is that most generally known, is ordinary concrete composed of Portland cement mixed with ballast, or broken stone and sand. The other, which is the best, in the

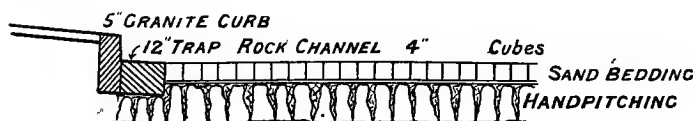


FIG. 1.

author's opinion, for this purpose, is that of the *bêton* horizontal wall or slightly cambered arch. The first method consists in preparing concrete upon boarded platforms, or bankers, in various proportions, the method adopted being usually as follows: To four parts of broken stone or ballast two parts of sharp clean sand are added, and one part of Portland cement. These are turned over twice in a dry state, and then water is added out of watering-pots (fitted with a rose) very gently, while the mass is turned over twice again in a wet state. This is then placed in the trench prepared for the foundation and thoroughly consolidated by ramming, and brought up to the proper surface with a shovel, care being taken that

the concrete is placed in position within fifteen minutes from its mixture.

The second system, which the author has described as the "bêton," is the method which is employed in the city of Liverpool, where the traffic is of the heaviest description; and this method will be given somewhat in detail, as it will probably be interesting. The ground having been prepared in the usual way, and the channel and curb stones fixed in position, a stratum of stones

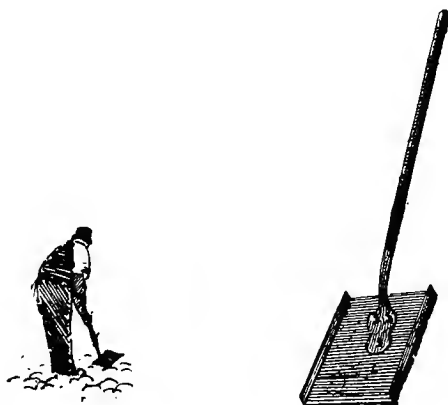


FIG. 2.

(which should by preference be of a non-absorbent character) broken so as to pass all ways through a 3in. ring, is spread evenly over the surface of the ground, and upon this is placed a layer of cement mortar mixed in the proportions of one of Portland cement to six of fine, sharp, clean gravel in the method to be described hereafter. Upon this layer of mortar is placed another layer of broken stone—the whole of the stones in each

layer to be thoroughly watered while the work is proceeding—and this stone is forced into the interstices of the first layer by the use of flat beaters of wrought iron weighing 16lb. each, shaped like square shovels, with handles at an angle of 33deg., as shown in Fig. 2.

This process is repeated until the proper level and contour is reached, and the surface is finished off parallel to the exact curvature of the carriageway, the proper form of which will be treated hereafter.

The foundation thus prepared is left until the concrete is sufficiently set or hardened to receive the pavement, which, if possible, should not be less than ten days, although this period may be shortened, where the exigencies of the traffic render it imperative, by strengthening the proportion of cement to the gravel, care to be taken in all cases to periodically water the surface of the concrete to assist the ultimate hardening, and in very hot weather it is advisable to cover the surface of the concrete with old cement-bags thoroughly saturated with water.

The proportions of broken stone, gravel, and cement used in such a concrete are as follows :

Before Mixing.—Broken stone, eight parts ; gravel, six parts ; cement, one part.

After Mixing.—Broken stones and gravel, mixed together, eleven parts ; cement, one part ; three parts of gravel having been expended in filling the interstices of the stones.

The method adopted for ensuring that the cement mortar shall contain the proper proportions as carried out in Liverpool is as follows : An apparatus is used

consisting of a set of double mixing boards, each 7ft. by $3\frac{1}{2}$ ft., having $1\frac{1}{2}$ in. deal sides and back 9in. high, and $1\frac{1}{2}$ in. deal bottom lined with sheet iron. A partition in the centre divides the board into two compartments; at the back of each compartment is a box for measuring the gravel, with a capacity of one cubic foot, 14in. square at the top, 10in. square at the bottom, and 12in. deep. It is hinged to the back of the board by strong iron eyes and bolts.

Any number of mixing boards being placed side by side, about 1ft. apart, the water supply is arranged as follows: A length of flexible tube is attached at one end to a hydrant on the nearest water service, and at the other end to the ball-tap of a sheet-iron regulating cistern, containing 18 gallons, fixed on a light angle-iron frame, about 4ft. from the ground to the bottom of the cistern; this is placed at one end of the series of mixing boards. Opposite to the inlet pipe is an outlet pipe of flexible tubing attached to the cistern by brass unions; water is conveyed through this pipe to a horizontal wrought-iron pipe, 7ft. long, supported upon light iron standards placed over the back of each mixing board. Attached to this pipe is a pair of brass swivel rose-ended pipes with stop-taps; these roses are so arranged as to discharge the water in a gentle rain-like spray over the centre of each mixing compartment. This arrangement may be extended to any number of boxes, the service pipes being connected by flexible tubing.

The cement is measured in light iron bowls having a capacity of one-sixth cubic foot.

The usual arrangement for mixing concrete is as follows: The mixing boards are placed with their backs

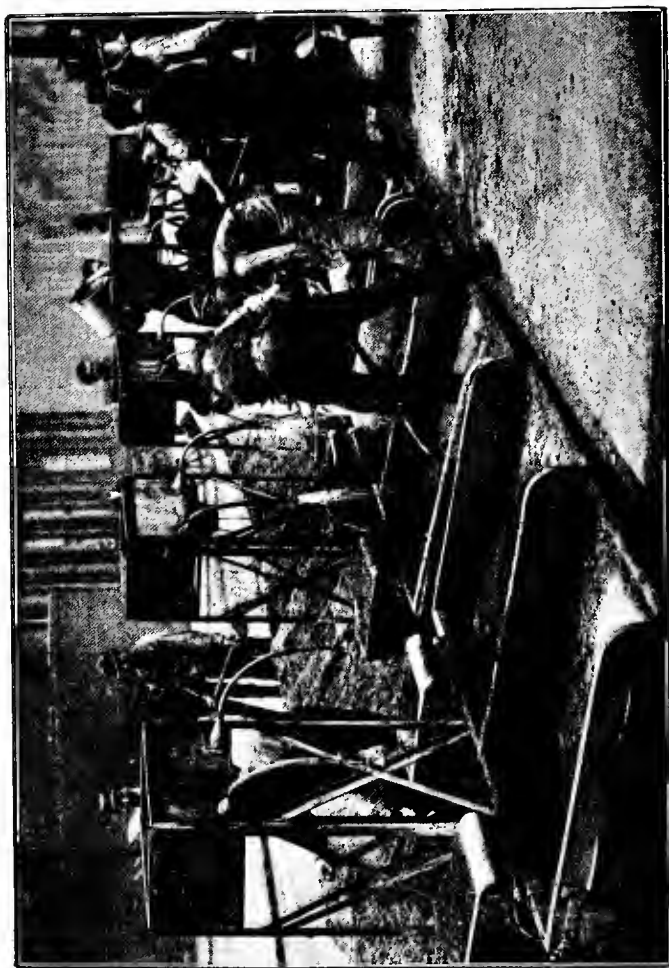


FIG. 3.

to a heap of gravel, the cement being stored at one end, also at the back of the boxes; a labourer with a mixing shovel is detailed off to each mixing compartment; a man at the back fills each measuring-box with gravel; the mixer in front tips over this box with his shovel, emptying the gravel into the mixing board; a boy brings a bowl full of cement from the store and spreads it over the gravel; the mixer turns over the contents of his board until the cement and gravel are thoroughly mixing in a dry state; he then turns the tap of the rose-pipe, and allows the water to flow over the mixture until sufficient moisture for setting is obtained, the quantity of water used varying with the dampness of the gravel; the concrete is now thrown into wheel-barrows and conveyed to its destination. One mixer in nine hours can turn out ninety such mixings, which is equal to $6\frac{1}{2}$ cubic yards.

Fig. 3 shows the operation as actually in work.

In concluding these remarks, it is almost unnecessary to say that great importance must be attached to the cement which is used, but this question is one that has been so largely dealt with in many treatises upon the subject that the author does not intend to attempt to give a specification that would meet all the requirements of the case; but he ventures to think that a considerable amount of difficulty would be overcome if the Council of the Institution of Civil Engineers would prepare a standard specification and system of tests for Portland cement to be used for this and other purposes.

WIDTH AND CONTOUR OF CARRIAGEWAYS.

The width between the curbs of town streets is generally fixed by the buildings already erected, but the proportion that the carriageway should bear to the footwalks is a matter for the consideration of all town engineers, and it is questionable whether hitherto this matter has received a proper amount of attention and discussion.

For ordinary vehicular light traffic any multiple of 8ft. is a good width to give between the curbs, as such vehicles can safely pass each other when moving rapidly, if each is allowed a width of 8ft.; but in cities where loaded vans are permitted, local considerations as to the legal width these vans may be constructed, and the amount of overhang that the loads may take, must of course be considered. As a matter of fact, the author thinks that roadways have hitherto been constructed too wide in this country in proportion to the footwalks, as where the traffic is considerable it is far better that it should proceed more slowly, and fall in line with each other, than that the roadway should be of inordinate width, and thus curtail the available space for the pedestrian traffic which increases in much faster ratio than that of the vehicular traffic. And it must be remembered that wide roadways mean more scavenging, more watering, and more expense in maintenance. The annexed diagrams (Fig. 4) show

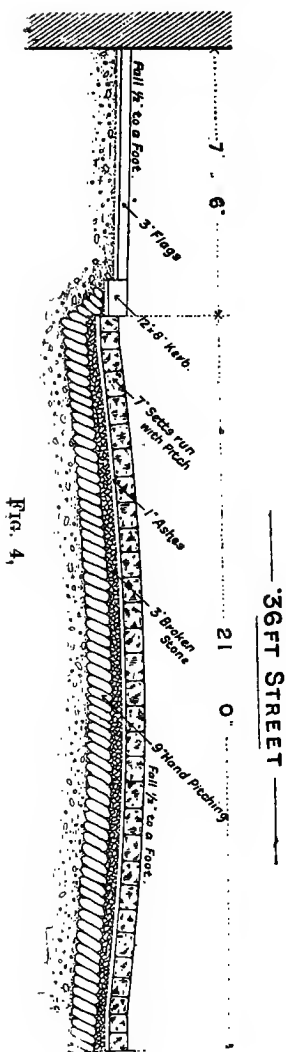
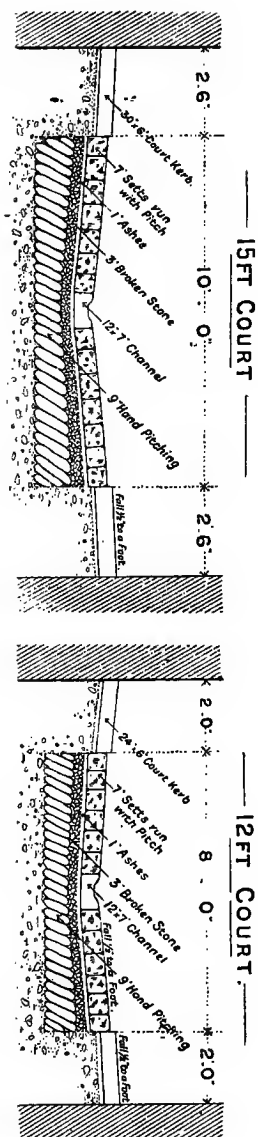


FIG. 4.

some sections of streets in the town of Nelson which have been prepared and issued by the borough surveyor, Mr. J. W. Bradley, A.M.I.C.E., in order to guide builders and others in the construction of private streets, and which are an excellent guide for the purposes for which they were intended.

In streets with excessive cross-fall, or what is known as a "hanging" road, a second curb is to be placed as shown, and the rise from channel to curb on the low side is not to be less than $1\frac{1}{2}$ in., as shown in Fig. 5, the particulars given thereon being excellent.

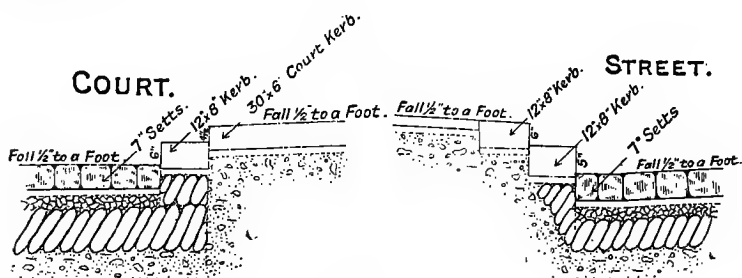


FIG. 5.

With regard to the contour or profile which the finished surface of the roadway should bear, this is governed to a very large extent by the description of the material with which the roadway is to be paved; for the only object in deviating from a truly level surface is to get rid of the surface water, and if in order to effect this object too much barrel is given to the roadway, it becomes inconvenient and even dangerous for the vehicles passing over it. For macadamised roads a rough-and-ready rule is to keep

the centre of the roadway level with the heel of the footpaths on each side. But with paved streets more

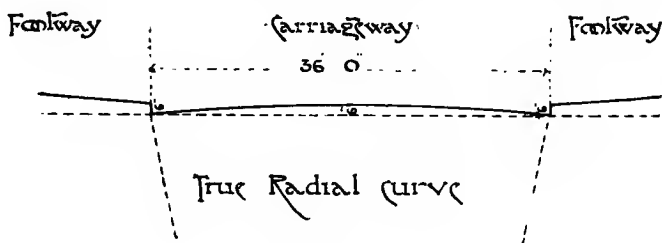


FIG. 6.

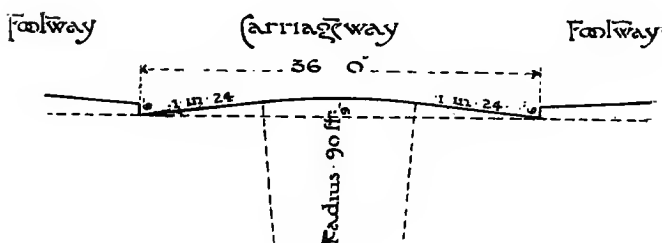


FIG. 7.

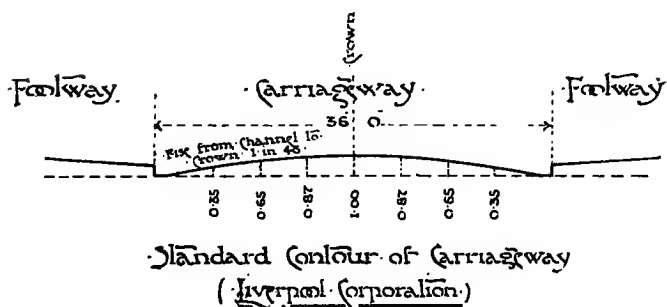


FIG. 8.

care must be exercised, and the accompanying sketches are given as examples of contours for carriageways. (See Figs. 6, 7, and 8.)

DESCRIPTIONS OF VARIOUS PAVEMENTS.

The selection of the material to be used for the purpose of paving any street carriageway is one that must be guided by the class of traffic and local feeling and surroundings.

Eliminating macadam for the reasons stated in the introductory remarks, the following list may be taken as materials which are either suitable or have been used for street pavements in this country :

- (1) Boulders or cobbles.
- (2) Setts of soft stones, such as sandstone, grit, whinstone, etc.
- (3) Setts of syenite or granite.
- (4) Blocks of wood of various descriptions.
- (5) Asphalte.
- (6) Brick.
- (7) Sundry materials, such as scorix blocks, cork composition, etc.

Boulder Pavements.

With regard to boulders or cobbles, although streets are still paved with these materials in some parts of England, especially in the Northern districts, they are a most unsuitable and insanitary material, and ought to be discouraged in every possible manner. They

make an exceedingly noisy pavement, and it is impossible to joint them closely, so that an extra cross-fall has to be given to the section of such a street in the vain endeavour to drain the surface. They are consequently almost impossible to scavenge properly, and filthy moisture accumulates between the stones. The jolting over such a pavement is exceedingly detrimental to vehicles, and horses' legs and hoofs suffer from the unevenness of its surface.* It is almost impossible to repair such a street when it is disturbed, as there seems to be no homogeneity, and if the surface is once disturbed it is difficult to again make it firm.

The draft specification for a street of this description may be taken as follows: The boulder paving should be selected water-worn or river-bank cobbles, or boulders of uniform quality set upon a hand-pitched foundation 6in. deep, the boulders being about 8in. in depth laid upon 3in. of rock sand as a cushion bed. The boulder stones to be not less than 5in. nor larger than 7in. on the bed, each superficial yard of paving to contain not fewer than forty nor more than fifty of such stones, the joints to be well crossed and racked with pea gravel, and the surface of the boulder paving to be covered with a coating of clean, sharp shingle not less than 1in. in thickness. In some cases the large stones are selected to be put on the haunches of the roadway, and the smaller stones in the centre.

Roadways of this description of pavement cannot be recommended.

* It has been found by experiment that it requires about 280lb. tractive energy to move one ton on a boulder-paved street as against 30lb. on asphalte.

Gritstone Setts.

Sandstone, gritstone, whinstone, etc., are only employed for paving purposes where these stones abound and are cheaply quarried. In Lancashire and Yorkshire, they are still used to a considerable extent where the traffic is too heavy for macadamised roads and on steep gradients. None of these stones, however, are very durable, even though care is exercised to select them from a reputed quarry. Major Isaacs, in his paper on "Carriageway Pavements for Large Cities,"* states with regard to this description of pavement that they "should consist of a hard light-brown or yellowish-brown grit and not too close a fibre." He further states that "the setts must be cut so that the grain of the stone runs parallel to the length of the sett, and consequently at right angles to its width," otherwise they will soon wear into holes.

Setts of this description are generally larger than those made of granite, as they give a better foothold. Their sizes vary from 8in. to 10in. in depth by from 4in. to 8in. in width by from 7in. to 10in. in length, and they are laid on a well-rolled foundation of foundry ashes or clinker with joints about $\frac{1}{4}$ in. in width, which are grouted in with dry gravel or foundry ashes, and afterwards flushed up with a hot bituminous mixture similar to that which will be described for granite sett pavements.

Where good foothold is required and the traffic is

* *Journal of the Society of Arts*, vol. xlii., No. 2,143.

light, this pavement is not altogether objectionable in districts easily served by the quarries.

Granite or Syenite Setts.

This class of pavement is still much more used in the North of England than in the South, and has done, and is doing, good service. But it is undoubtedly a noisy pavement, although the outcry on this account has in the author's opinion been somewhat overdone. It is stated this pavement has a bad effect on the nervous system. But from the author's experience he is of opinion that the inhabitants of the North of England, as a rule, are not much troubled with nervous complaints. It is also stated that spaces between the setts are often left through which water percolates, and the concrete disintegrates if it happens to be weak at any point and the roadway breaks up. Further, that the wheels of vehicles pick up particles of the granite, carry them round, run over them, and leave them in lumps, thus ruining a road ! Neither of these statements have any semblance of fact where a granite sett pavement is properly constructed in an impervious manner upon a foundation such as has been described. And with regard to the wear, there is no pavement that has yet been discovered with so long a life as granite sett pavement properly laid with judiciously selected granite or syenite. The advantages of such a pavement may be summarised as follows :

- (1) Adaptability to most gradients.
- (2) Suitability for all classes of traffic.

- (3) Durability.
- (4) Fair foothold.
- (5) Ease of traction.
- (6) Minimum of dust and mud.
- (7) Fairly easily cleansed.
- (8) Fairly easily repaired.

The principal defects of this pavement are that in certain conditions of the atmosphere it may become somewhat slippery, and the noise is undoubtedly in some cases very excessive. It is also said that horses suffer from the continual jarring upon their legs and hoofs, but this has not been thoroughly substantiated. Too much stress cannot be laid upon the great importance of selection of proper stones. The syenites or Welsh granites are the best: they do not seem to wear so slippery as other classes of granite, and yet their life is very great, as will be presently shown.

On the question of the avoidance of excessive slipperiness of granite or syenite setts, the almost universal practice, as will be seen on reference to the table of replies from a number of cities and towns, which is given hereafter, is to throw sand or gravel upon the surface of the carriageway. This, no doubt, acts well for a time, but it causes mud, and consequent cost in scavenging; and, in addition, the sand or gravel tends to polish the face of the stone and ultimately render it more slippery. A better cure is to thoroughly sweep, or, better still, to wash and clean the surface, which greatly minimises the slipperiness of the class of pavement which is now being dealt with.

The size and shape of the setts are matters that have been much disputed. For stability a certain proportion must exist between the depth, length, and breadth, and 7in. has been fixed as a sufficient and proper depth for any class of traffic. The width is somewhat controlled by the size of the horses' hoofs, and about 4in. is now allowed to be the maximum width. The length is governed principally by the ease of handling of the sett by the pavior, and so that each sett will break joint properly with its neighbour, and not be too long, so as to conform to the contour of the road. Stones, if of too great a length, are apt to ride and tilt. Nine inches may be considered as quite long enough. Taking the question of cost into account—and cost of this description of paving, be it remembered, is considerably affected by weight when carriage of the stone has to be considered—the following sizes of stones may be taken as satisfactory* :

Setts	...	6 $\frac{1}{4}$ in. $\times$ 3 $\frac{1}{4}$ in. $\times$ 5in. to 7in. long
„	...	7 $\frac{1}{4}$ in. $\times$ 3 $\frac{1}{4}$ in. $\times$ 5in. to 7in. „
Cubes	...	3 $\frac{3}{4}$ in. $\times$ 3 $\frac{3}{4}$ in. $\times$ 3 $\frac{3}{4}$ in.
„	...	4in. $\times$ 4in. $\times$ 4in.
Blocks	...	4in. $\times$ 4in. $\times$ 6in. deep
„	...	3 $\frac{1}{4}$ in. $\times$ 3 $\frac{1}{4}$ in. $\times$ 6 $\frac{1}{4}$ in. „

It is of the greatest importance that the setts should be thoroughly square and not taper, and that the dressing should be most carefully carried out, and the deviation from the specified size should in no case

* In Paris, after considerable research into the question, the engineers of the Ponts et Chaussées decided that the size of the paving stones, which used formerly to be 9in. square, should be 4in. wide by 6 $\frac{1}{4}$ in. long by 6 $\frac{1}{4}$ in. deep, the stone that is used being a grit sandstone from the forest of Fontainebleau.

be allowed to exceed $\frac{1}{4}$ in. in depth and breadth respectively, and there ought not to be a difference of more than $\frac{1}{2}$ in. between the broad and thin ends of the setts.

It is highly important that all setts should be gauged and dressed uniformly, and that they should be laid as close together as possible, because the slight inequalities provide quite sufficient joint for the grouting, and the nearer the setts are laid together the less is the noise of the traffic and the less is the liability of the arrises to wear. It is also important to lay the setts on a cushion bed of sand of about $\frac{1}{2}$ in. in thickness, as this transfers the pressure to the foundation equally, and gives some elasticity to the bed; this prevents the stones being crushed, which might otherwise take place if they were laid directly on the rigid concrete foundation. The cushion bed must be of fine sand, as otherwise there might be a liability of the setts to ride. This bed is also of great value where the setts are grouted with a bituminous mixture, and not cement—the former in the author's opinion being preferable, as he will point out hereafter.

In deciding upon the setts to be used in comparing the quoted prices, the relative specific gravities should be taken into account, as the lighter setts will, of course, cover a larger area of pavement. For instance, if 500 yards of paving required 151 tons of setts with a specific gravity of 2.60, and assuming the price to be 25s. per ton, the cost would be £188 15s.; whereas it would take 168 tons of setts with a specific gravity of 2.90 to cover the same area, and if the price of these setts was 24s. per ton, the cost would be £201 12s.;

so that there would be a saving in adopting the higher-priced stones provided their durability was equal.*

It may be convenient at this point to give the following standard specifications for paving streets in the city of Liverpool, which are issued to builders and others who are laying out new streets. They are as follows :

FIRST-CLASS STREETS.

Carriageway.—Excavate or fill in the ground, as the case may be, to the requisite level, and remove all surplus material. Properly form and trim off the surface and thoroughly consolidate same, and then lay a foundation of not less than 6in. of Portland cement concrete, Corporation standard. The paving shall consist of granite or syenite setts, $3\frac{1}{4}$ in. wide by $6\frac{1}{4}$ in. deep, from North Wales or other approved quarries, laid in regular, straight, and properly-bonded courses, with close joints, and to be evenly bedded on a layer of fine gravel $\frac{1}{2}$ in. in thickness. After the paving is laid, the joints shall be filled with hard, clean, dry shingle; the setts shall then be thoroughly rammed and additional shingle added until the joints are perfectly full. The joints shall then be carefully grouted until completely filled with a hot composition consisting of coal pitch and creosote oil, and, finally, the paving is to be covered with $\frac{1}{2}$ in. of sharp gravel.

Crossings.—The crossings shall consist of three rows of 16in. by 8in. granite crossing stones, and the

* *Vide* "Street Pavements," a paper read before the Liverpool Engineering Society, February 14, 1894, by Mr. James Morgan, A.M.I.C.E.

remaining space shall be paved on each side of the crossing stones, to the full width of the footway, in a similar manner to the carriageway. The crossing stones shall be of granite, of a quality to be approved by the city engineer, dressed perfectly true, and out of winding on the face; the sides and joints to be perfectly square and accurately dressed throughout their entire depth; the stones to be bedded on cement concrete, the joints to be filled with shingle and grouted in a similar manner to the paving. A triangular groove, 1in. wide by $\frac{3}{4}$ in. deep, to be formed along the upper surface of each stone. No stone to be less than 3ft. in length.

Footways.—The footways shall be paved with Yorkshire or Lancashire flags of the best quality, not less than 3in. thick. No flag to measure less than 2ft. in width nor to be of less area than 6ft.; to be solid, free from laminations, the upper surface to be true and free from windings or hollows; the joints to be squared the whole thickness. The flags to be laid on a bed of fine gravel, with close, neat joints, flushed in mortar, and in uniform courses breaking bond. The joints to be dressed after laying, where necessary.

Channels.—The channel stones to be of granite or syenite, of a quality to be approved by the city engineer, and to be not less than 3ft. in length. The upper surface, if not self-faced and perfectly true, must be accurately worked out of winding, the bed even and parallel to the face, the sides and ends truly square; the stones to be bedded on cement concrete, and the joints to be filled with

clean shingle and grouted in a similar manner to the paving.

Curbs.—The curbstones to be granite or syenite, straight or circular, as required, 6in. thick at top, 7in. thick at 5in. below, and not less than that thickness for the remainder of the depth; to be not less than 12in. deep, nor less than 3ft. in length; to be carefully dressed on top, 8in. down the face and 3in. down the back; the remainder of each stone to be hammer-dressed; the heading joints to be neatly and accurately squared throughout the entire depth.

SECOND-CLASS STREETS.

Carriageway.—Excavate or fill in the ground, as the case may be, to the requisite level, and remove all surplus material; properly form and trim off the surface, and thoroughly consolidate the same, and then lay a foundation of (a) not less than 6in. of Portland cement concrete, Corporation standard, or (b) not less than 6in. of bituminous concrete, consisting of clean and angular broken stone, grouted with a hot composition consisting of coal pitch and creosote oil, covered with chippings, and thoroughly consolidated by rolling with a roller of sufficient weight. The paving shall consist of granite or syenite setts 3in. wide by 5in. deep, or of granite or syenite 4in. by 4in. cubes from North Wales, or other approved quarries, laid in regular, straight, and properly-bonded courses, with close joints, and to be evenly bedded on a layer of fine gravel $\frac{1}{2}$ in. in thickness. After the paving is laid the joints shall be filled with clean, hard, dry shingle; the setts

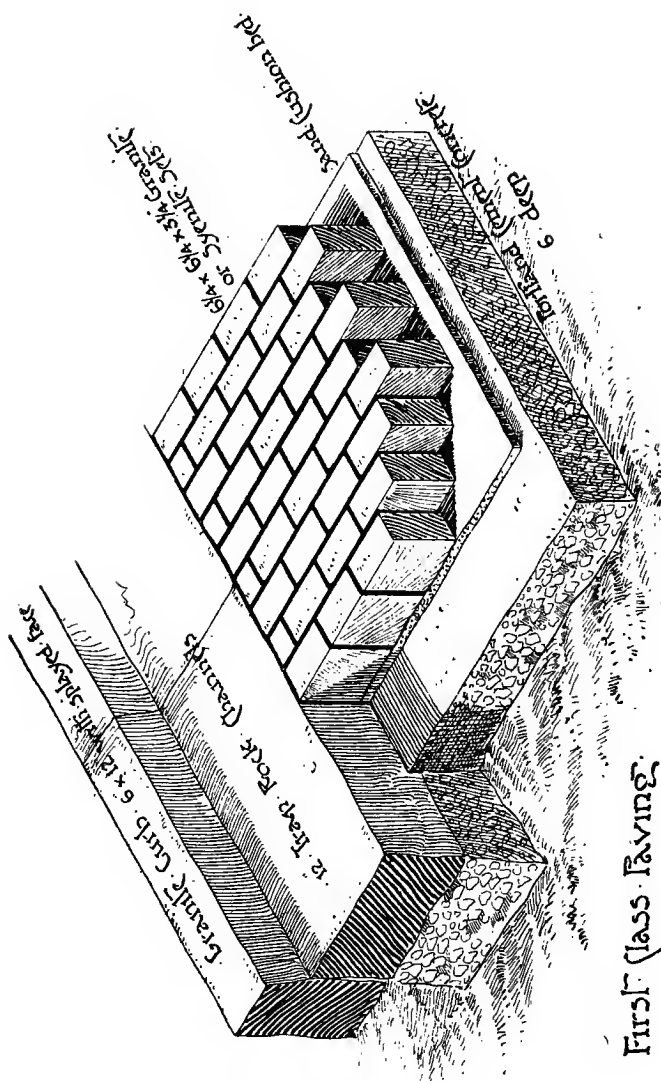
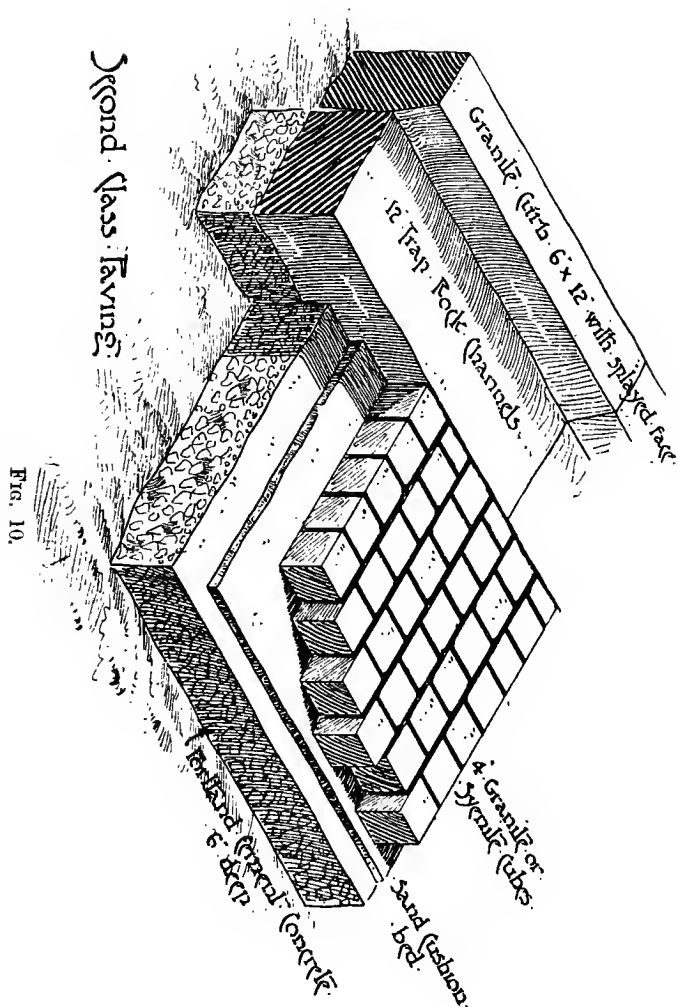


FIG. 9.



shall then be thoroughly rammed, and additional shingle added until the joints are perfectly full. The

joints shall then be carefully grouted, until completely filled, with a hot composition consisting of coal pitch

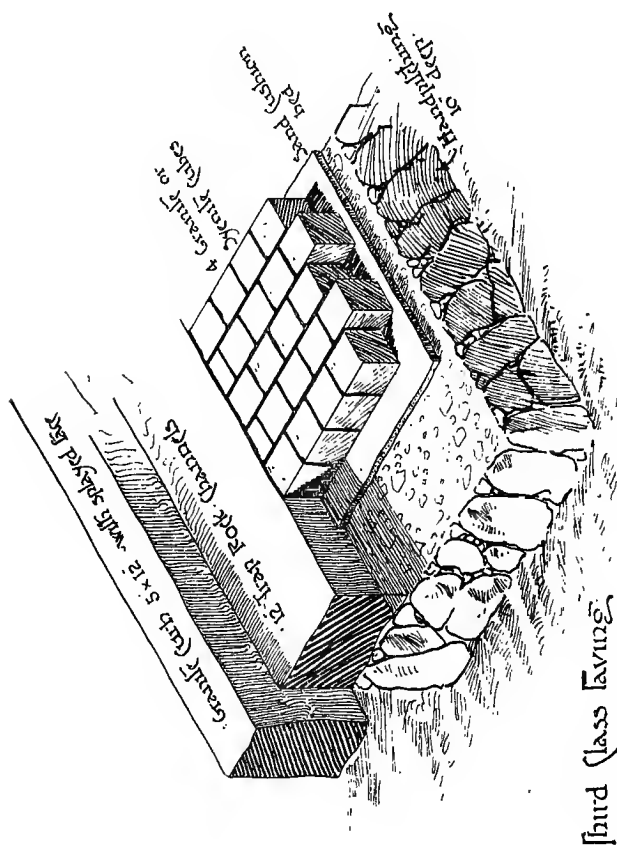


FIG. 11.

and creosote oil, and, finally, the paving shall be covered with $\frac{1}{2}$ in. of sharp gravel.

The crossings, footways, channels, and curbs shall be the same as specified for first-class streets.

THIRD-CLASS STREETS.

Carriageway.—Excavate or fill in the ground, as the case may be, to the requisite level, and remove all surplus material; properly form and trim off the surface, and thoroughly consolidate the same, and then lay a foundation of hand-pitched rock, 6in. in depth, set on edge in the manner of a rough pavement. Over this a coating of gravel is to be laid of sufficient thickness to fill in the interstices and to form a smooth surface to the foundation, which must be thoroughly consolidated by rolling with a steam-roller before the paving is laid. The paving shall consist of 4in. by 4in. granite or syenite cubes from North Wales, or other approved quarries, laid in regular, straight, and properly-bonded courses, with close joints, and to be evenly bedded on a layer of fine gravel $\frac{1}{2}$ in. in thickness. After the paving is laid the joints shall be filled with clean, hard, dry shingle; the setts shall then be thoroughly rammed, and additional shingle added until the joints are perfectly full. The joints shall then be carefully grouted, until completely filled up with a hot composition consisting of coal pitch and creosote oil, and, finally, the paving shall be covered with $\frac{1}{2}$ in. of sharp gravel.

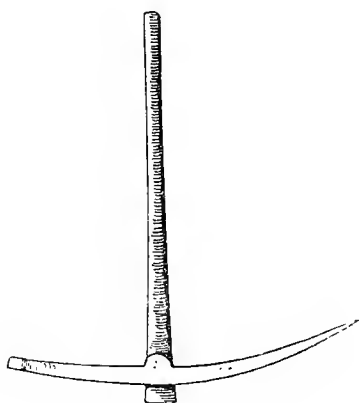
The crossings, footways, channels, and curbs shall be the same as specified for first-class streets.

Figs. 9, 10, and 11 show in detail the preceding descriptions of pavements.

In connection with the above specifications and drawings, it may be of interest to give the following sketches (drawn to scale) of some of the tools which are employed to execute this work.

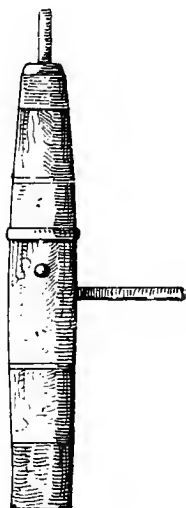
The navy hack is a form of pickaxe weighing about 12lb. (Fig. 12).

The pavior's rammer, made of hard wood, and bound with iron, weighs about 40lb. (Fig. 13).



Navy Hack

FIG. 12.



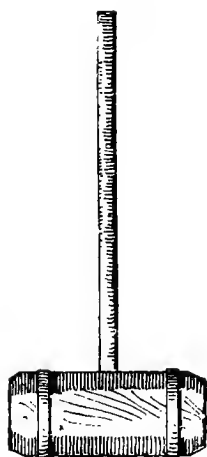
Rammer

FIG. 13.

The concrete smoother, for floating up the finished surface of the concrete foundation to a smooth face, weighing about 11lb. (Fig. 14).

The flagger's maul for setting flags, kerbs, etc., weighing 26lb. (Fig. 15).

The pavior's hammer, weighing 4 $\frac{3}{4}$ lb., with which the pavior manipulates the cushion beds and taps the stones into place. (Fig. 16).



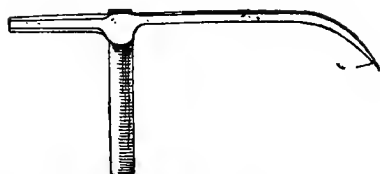
Flaggers Maul

FIG. 14.



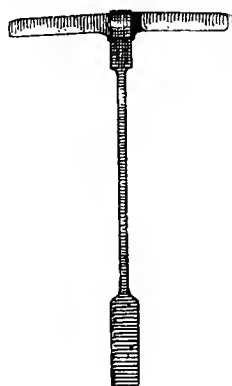
Concrete Smoother

FIG. 15.



Paviors Hammer

FIG. 16.



Ramming Iron

FIG. 17

The cramming iron, weighing 6lb., and used for "racking" the joints. (Fig. 17).

The sett - dresser's hammer, weighing 7lb., with which the sett is dressed and squared. (Fig. 18).

And lastly, the sett - cleaner's hammer, weighing 2½lb., with which the grouting of bitumen or cement is knocked off old setts preparatory to their being reused. (Fig. 19).



Sett Dresser's
Hammer

FIG. 18.



Sett Cleaner's
Hammer

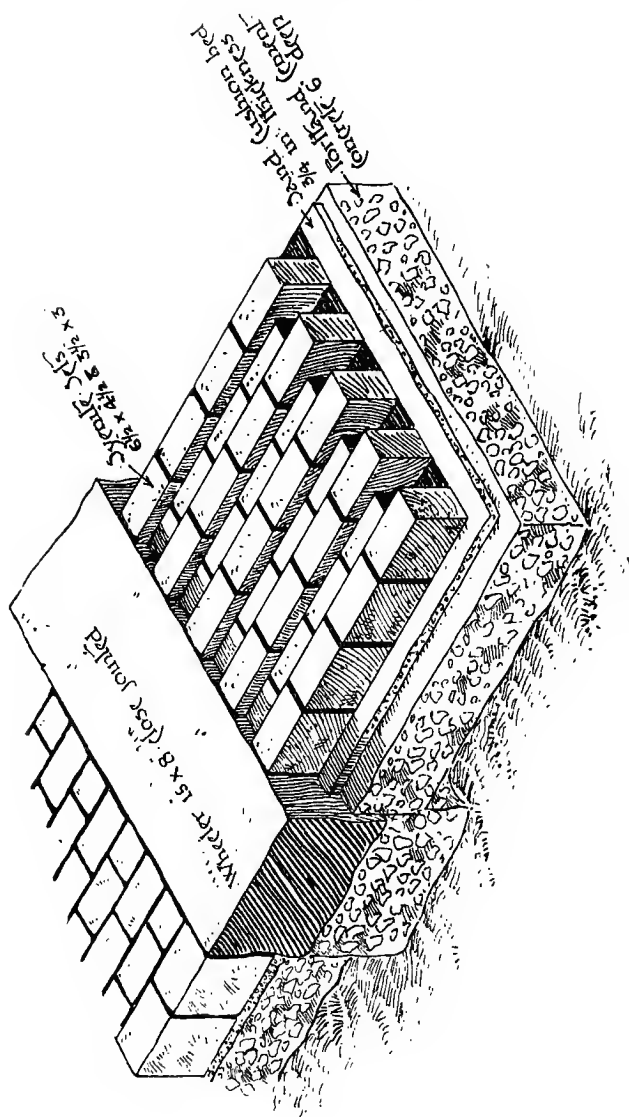
FIG. 19.

A few words upon this method of cleaning setts may here be advisable. The author found that the expense of cleaning setts by hand with the above tool was tedious and costly, as on one occasion, which was carefully noted, it took seventeen men ten and a half days to clean 677 superficial yards of 4in. cube setts, which was equal to 10½d. per square yard.

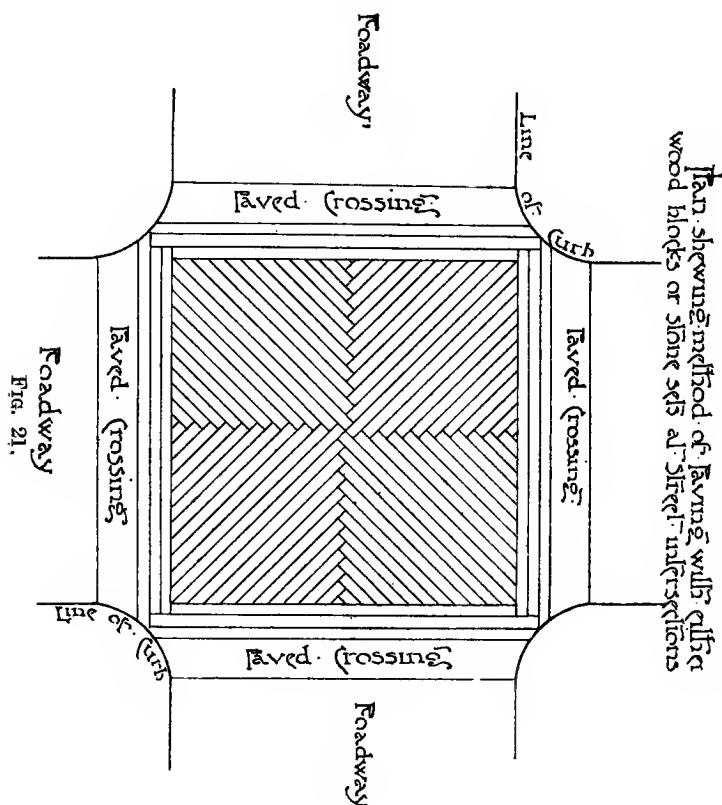
He consequently tried, with every success, the

process of boiling the old setts in a pitch-boiler, the method and cost being as follows: Creosote oil is heated in an ordinary road pitch-boiler to about 266deg. Fahr., and the setts are thrown in and allowed to remain ten or twelve minutes, when they emerge thoroughly clean and fit for use, at a cost of 4·07d. per superficial yards; the labour of two men in this method being sufficient, as against seventeen men in the former case working for the same time.

It will be interesting here to note the relative wear of steel tram rails and granite setts, and the author has been able to ascertain some valuable facts from actual trial in the city of Liverpool, where there are nearly 50 miles of equivalent single lines. It was found by actual measurements and weights that in ten years the wearing surface or treads of Bessemer steel rails had worn down half an inch under a tramway traffic of 318,589 tons per annum on each rail, which, if reduced to 100,000 tons per annum, would represent a wear of 0·015in. per annum. The abutting syenite setts showed very little wear except where the edges next the steel rails were rounded off. The lesson to be learnt from this is that the abutting setts should not be laid, as is generally the custom, "proud" of the rails, but the reverse where the setts are of exceptionally hard quality. Lastly, the author desires to draw attention to the advantage of "wheelers" for the haulage of heavy loads up steep gradients. They should be of granite or syenite, the upper surface smooth quarry-faced, the joints dressed down squarely to the full depth so as to avoid the chance of tilting. They should be, if possible, 24in. in width and 8in. to



12in. in depth, in lengths of not less than 3ft., laid on a good bed of Portland cement concrete to a gauge of about 6ft. 6in. centres, with a horse track between



paved with setts having a wider joint than the ordinary setts of a roadway so as to give better foothold—the drawing (Fig. 20) will explain this.

The objection to this form of paving between the wheelers is the fact that the arrises of the setts wear

off, they become rounded, and the object of the prevention of the slipping of the horses drawing the loads is defeated.

With reference to the method of arranging the courses of paving setts at the corners or intersections of streets, many methods are adopted, almost every municipal engineer having his own pet method of effecting this work. But the author believes that the plan shown in Fig. 21 has many advantages—viz., that the courses of the setts are almost at right angles to the traffic, it is easily set out, the joints butt fair and square against each other, and very little cutting or tooling of the stones is necessary

WOOD PAVEMENTS.

The increased use of wood as a paving material, especially in London and the suburbs, has been remarkable during the last few years, the reason, no doubt, being its near approach to noiselessness without that slipperiness attributed to asphalt. It is said to have been first laid in this country in the Old Bailey, London, in the year 1839, but as it was then laid in large pine blocks it was impossible to avoid sap, and having no foundation, it soon failed. Since then there has been a steady evolution through almost every description of wood, such as pine of all sorts, oak, ash, beech, elm, the favourites for a long time having been Memel and Dantzic fir and some descriptions of American pines; the more modern descriptions being those from Australia, such as Jarrah, Karri, and others of the eucalyptus or blue-gum types. Whatever wood is selected it should be thoroughly sound, and free from all traces of sap, close grained, and uniform in quality, free from knots or shakes; and every block should be examined by a trustworthy and experienced person before being used. It is not necessary to have "seasoned wood," as it appears from experience that the wood is better for having a little "life" in it.

It is claimed for the Australian woods that, though considerably dearer than Baltic or American deals,

their life is longer under the traffic, and that they require no creosoting, and, being close grained, they are more sanitary.

With reference to the question of creosoting the softer woods, this does not add to the life of the block, but renders it less absorbent, and consequently more sanitary. The creosote used should be specified to be heavy oil tar, free from all ammoniacal water, and contain not less than 5 per cent. of tar acids. Each block should be carefully examined before insertion in the creosoting chamber to avoid inferior blocks being used, which cannot be detected after the operation.

At least 10lb. of creosote oil should be driven into every cubic foot of wood, under such a pressure as will ensure this, and a few of the blocks should be cut in half from time to time to see if the creosote has thoroughly penetrated. Another method highly spoken of by Mr. Chas. Mason, the surveyor to the parish of St. Martin-in-the-Fields,[†] is that of boiling the blocks from about ten to fifteen minutes in a preparation called "Carbolinum Avenarius."

Whatever wood is selected, and whether treated or not, the blocks should be cut die square with the

* In the Strand, opposite the District Post Office, at the starting place for omnibuses going eastward, 6in. deal blocks wore through in twelve months, whilst Jarrah blocks substituted for them only wore 2½in. in three years. These were again substituted by Karri blocks, which have been down about twelve months. The superior durability of this class of woods is recognised by the London County Council, as they will grant loans for Jarrah or Karri woods for seven years, instead of five years for ordinary wood.

† *Vide* "Carriageway Pavements," a paper read at a meeting of the Incorporated Association of Municipal and County Engineers in London, on January 12, 1894.

fibre vertical, a convenient and much used size being 9in. by 6in. by 3in. on the face. Experiment has shown that on the question of the angle of the fibre of the wood to the traffic, the following results were obtained :

Vertical fibre	wore	.125	of an inch.
At angle of 75deg.	„	.147	„ „
„ 60deg.	„	.182	„ „
„ 45deg.	„	.250	„ „
„ 30deg.	„	.310	„ „
„ 15deg.	„	.375	„ „
Horizontal	„	.500	„ „

Thus it is evident that the blocks must be laid with the fibre of the wood quite vertical.

The foundation of a wood-paved carriageway must be of concrete, similar to that already described. In some cases a cushion bed of sand or fine gravel is laid upon the concrete about $\frac{1}{2}$ in. in thickness; in the London practice and elsewhere the blocks are laid directly upon the surface of the finished concrete. In the former case, it is found that the grouting (and on this point more will be said), if of bitumen, sinks into this cushion bed, and prevents the upheaval of the blocks, which sometimes occurs where this cushion bed is not provided.

There is also a difference of opinion on the question of joints between the blocks. In some cases they are laid with an open joint between them, about $\frac{1}{4}$ in. or $\frac{1}{8}$ in. wide, and this joint is filled up with "racking," composed of dry, clean, sharp, or rounded gravel or pebbles about the size of beans or small nuts, which is afterwards filled in with a bituminous mixture, con-

sisting of three of pitch to one of creosote oil, well boiled together in a travelling pitch-boiler on the Healey system.

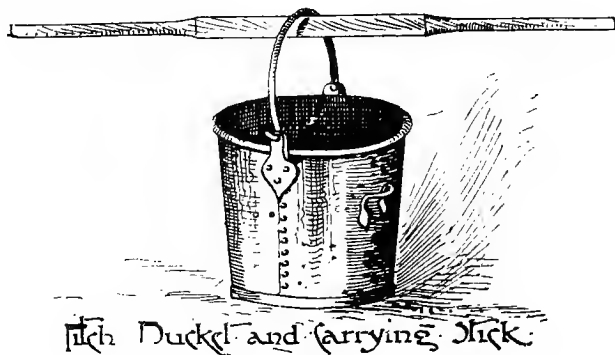


FIG. 22.

The pitch, when boiling, is usually drawn off into a bucket containing about 11 gallons, which is carried on a pole by two men on to the road which



FIG. 23.

is in course of paving and run into the joints. The bucket and carrying stick or pole are represented in Fig. 22.

This bucket is sometimes filled by means of a ladle or scoop holding about five quarts (Fig. 23).

A better plan, which the author has recently introduced, is to draw off the pitch from the boiler into a wheeled pitch-carrier holding 20 gallons, and so constructed that by means of a double lining filled with a non-conducting material the heat is retained for some time, and the pitch is easily poured on to

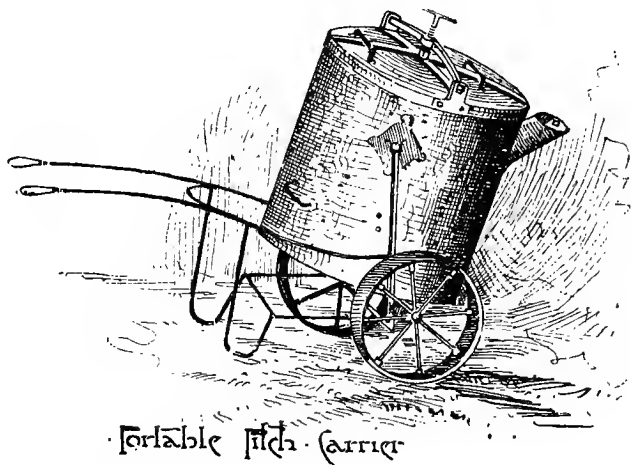


FIG. 24.

the surface of the roadway in such quantities as are required. Fig. 24 explains this machine.

It is found that wood is absorbent of moisture, with a consequent swelling, and it is contended that "racking" when employed enters into the sides of the blocks, and thus takes up the extra space required for this swelling or expansion, and prevents upheaval or the forcing away of the kerbs at the sides of the

carriageways. The expansion due to this swelling of the wood, owing to absorption of moisture, varies with

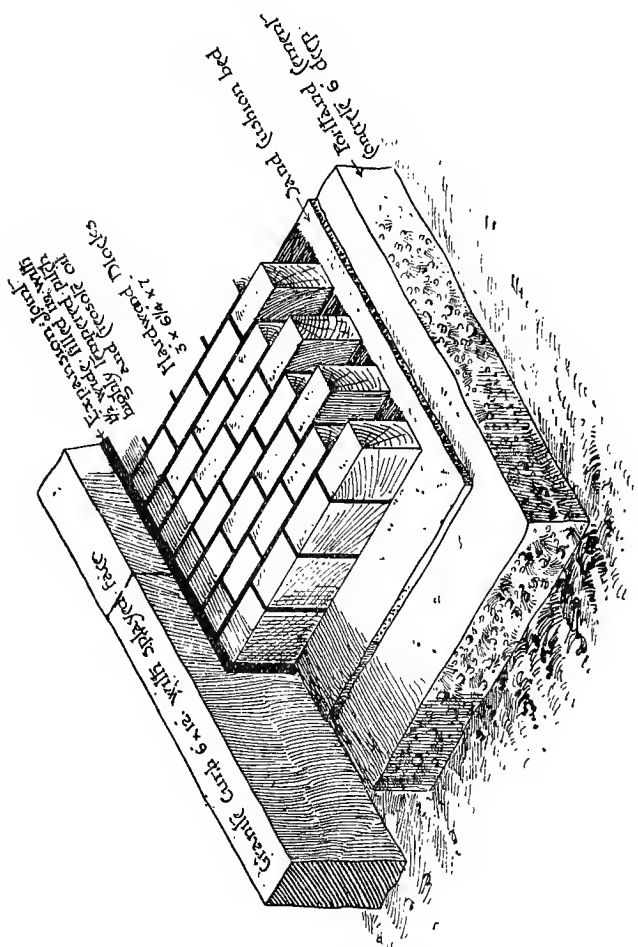
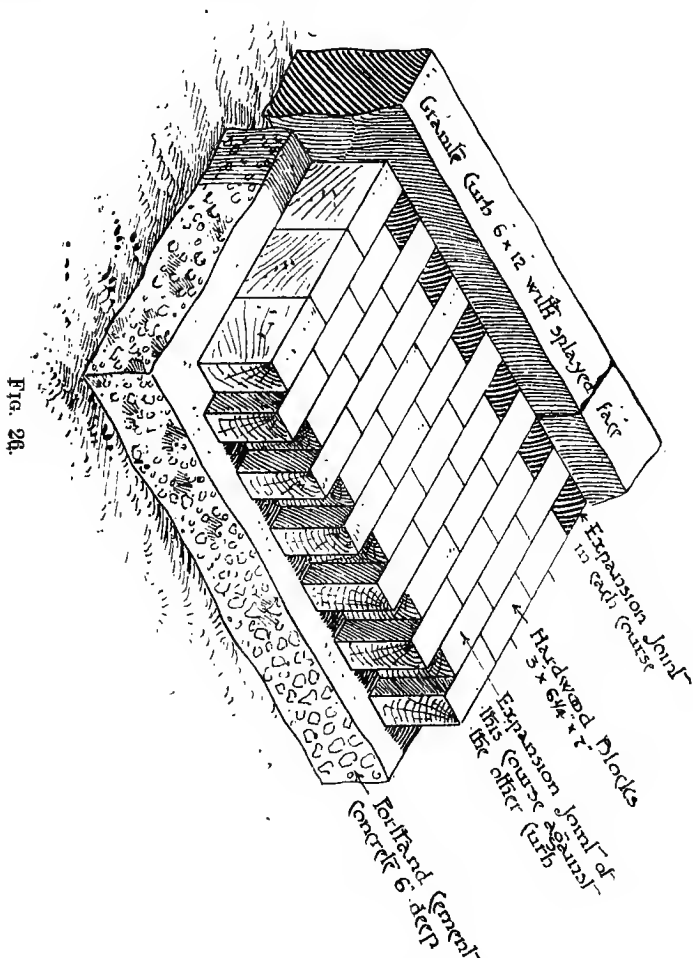


Fig. 25.

different woods; it is very small with the Australian hardwoods, but considerable with the softer pine

woods (unless chemically treated), amounting in some cases to as much as $1\frac{1}{4}$ in. in 8 ft. In the early



days of wood pavements great trouble was caused by this movement.

In order to prevent upheaval, or movement of the blocks, an expansion joint filled with clay is sometimes left about $1\frac{1}{2}$ in. wide parallel and close to the curb on each side of the carriageway; in other cases, "dog tothing" is resorted to, so that each transverse row of blocks has an expansion joint of about $4\frac{1}{2}$ in. The isometrical sketches (Figs. 25 and 26) will explain these systems.

It is said that where the bituminous grouting of joints is run into the surface of the street, the action of the sun and air causes evaporation and consequent decay of the jointing material, and that putting salt on the surface of the carriageway during snow has a deleterious effect upon it. If this is a fact, it could be avoided by finishing the joint with a grouting about $\frac{1}{2}$ in. in depth of Portland cement, but the author has had no experience of the kind, nor does he think it occurs.

Mr. Wm. N. Blair, the engineer to the Vestry of St. Pancras, London, has recently issued a very valuable report on the question of pitch and cement grouting for street pavements, by which it is clearly proved that pitch grouting is preferable to cement grouting for many reasons set forth in the report, and which may be summarised as follows. Pitch grouting allows the joints to be reduced to $\frac{1}{8}$ in. wide, thus soft wood blocks may be in close contact and so prevent the fibre spreading, and this preserves the life of the wood—it is more elastic than cement, and consequently absorbs expansion and gives way to contraction. It is also impervious, and the pitch joint next the wood helps to preserve it. Traffic may be turned on directly the joint is cool, and it is easier

applied than cement grouting. It further appears from the report that out of twenty surveyors of London vestries who replied to Mr. Blair's question on this point, fifteen preferred pitch grouting for wood, and ten out of twenty-four for granite paving; and of provincial towns fifty-five preferred pitch grouting for wood paving out of sixty-seven, and sixty-five out of seventy-five for granite paving. These results ought to settle this question definitely in favour of pitch grouting until some better material is discovered.

The further disadvantages of an open transverse joint between the blocks in wood pavement are that they expose the arrises of the blocks to attrition and rounding off by the traffic, thus making a bumpy and noisy road, and also that mud sticks in the joints which is difficult to dislodge, and thus adds to the slipperiness of this description of pavement.

The more modern practice, consequently, is to do away with all joints between the courses, and the blocks are laid close together, the sides and ends touching, hot tar being laid over the surface and brushed or "squeegeed" until it disappears between the blocks, expansion being provided for in the manner already described. In all cases of wood pavement it is necessary to cover the finished surface with a half inch coating of clean, sharp shingle, gravel, or pebbles about the size of beans or small nuts, leaving the traffic to squeeze it into the top surface of the wood, which preserves its life and renders it less slippery.

Wood is unquestionably an excellent pavement for streets of light traffic, but it would not stand the

crushing weights of a heavy mercantile traffic such as that in some of the streets in Liverpool or Manchester, where four or even six tons on a wheel is occasionally carried.

Nor can it be used on streets where the gradient is steeper than 1 in 27; for though its slipperiness may be much minimised by sanding or gravelling, there are times when the peculiar atmospheric conditions of our climate render it very slippery.

The following are some of the advantages claimed for wood as a pavement:

- (1) It is noiseless.
- (2) It manufactures no mud or dust in itself.
- (3) It offers very little resistance to traction.
- (4) It affords good foothold, except under certain conditions.
- (5) It is fairly durable.
- (6) It is fairly moderate in cost.
- (7) It is comparatively easily repaired.
- (8) It may be used on gradients up to 1 in 27.
- (9) It suits all classes of light traffic.
- (10) It has a good appearance.
- (11) It is fairly easily cleansed.

Upon the last of these qualifications much difference of opinion seems to exist. On the one hand, some eminent metropolitan surveyors have stated that even where there are cabstands no nuisance or smell of any kind is observable; on the other hand, Major Isaacs, F.R.I.B.A., A.M.I.C.E., the well-known surveyor to the Board of Works for the Holborn District, states: "Wood pavement has one most

serious disadvantage—it offends more than any other against public hygiene. If time would permit, I could quote the opinions given by authorities both at home and abroad in proof of this assertion. But I will content myself by asking you to rely on the evidence afforded by your own sense of smell as to this. Let anyone dwell, say, for twenty-four hours by the seaside or in the pure air of a rural district, and travel to town, alighting, for example, at the Victoria Station, the roadways of which, as you know, are paved with wood. What greets him on arrival? The moist sickening odour given off by the pavement in question. You will say this is mainly or entirely owing to the circumstance that the wood pavement is under a glass roof on which the rays of the sun at times fall fiercely. But step across the station yard and traverse Victoria-street. The same sickening odour—if not quite so overpowering as in the station itself—follows you. And this leads me to say, avoid using wood pavements in narrow streets, or even in comparatively wide streets, where the height of the buildings which abut on the same prevents the free passage of air.”*

Major Isaacs then goes on to speak of the advantages of thorough cleansing with water of all street surfaces where paved; and in the case of wood pavements, of washing them with a weak solution of carbolic acid, or soluble creosote and water in the proportions of 1 to 2,000. With these remarks the

* *Vide* “Carriageway Pavements for Large Cities,” by Lewis H. Isaacs, F.R.I.B.A., A.M.I.C.E., Surveyor to the Board of Works for the Holborn District. *Journal of the Society of Arts*, vol. xlii., No. 2,143, page 61.

author cordially agrees, and is of opinion that the water supply of any large city should be so abundant and unstinted that all the paved streets, and even the footwalks, in the busiest parts of the city should be frequently washed and flushed down. The trouble in connection with slipperiness, both in regard to asphalte as well as wood, would then almost entirely vanish.

Some attempt at one time was made to ascertain if the death-rate was increased by the introduction of wood pavement owing to its alleged insanitation, but the result of the investigations was to show that so far as these statistics were concerned, there was no foundation for the charge.

In cities where granite setts are principally used on economic grounds, an outcry is sometimes made by the owners of properties abutting on the streets against the use of stone setts, and a clamour is raised for wood pavement. It may be of use to some of the readers of this book to know that in Liverpool, wood pavement is laid instead of granite setts if the abutting owners prepay 60 per cent. of the estimated first cost of the wood pavement, the Council maintaining it for ten years, reserving to themselves the right to substitute granite setts for the wood at the end of that period if they should so decide. This seems to be a good way out of a difficulty, and avoids any feeling that certain districts or streets are favoured more than others, which is often a stumbling block in the way of all municipal engineers and surveyors.

Asphalte Pavement.

The use of mastic asphalte for carriageway pavements of much traffic is now almost a thing of the past, so that the following remarks will be confined to the use of compressed asphalte.

An authority upon street pavements has said "granite has given way to wood, so wood will have to give way to an impervious material as asphalte, or some future improvement upon it," and there can be no doubt that if an impervious pavement can be found free from all joints and thoroughly durable, smooth, yet without slipperiness, it should be the pavement of the future.

With the exception of the one great point of slipperiness, asphalte nearly complies with all requirements, and in other countries where the climate is not so much against it as in England, many thousands of yards of asphalte are yearly laid. In the United States about seven million square yards of Trinidad asphalte have been laid, and in Berlin, Vienna, and other continental cities, asphalte pavements are the rule instead of the exception.

The asphaltés chiefly used for carriageway pavements in Europe are those from Val de Travers, in Switzerland, Seyssel, in France, Limmer, in Hanover, and also some Sicilian mines. It is a natural rock consisting of pure carbonate of lime impregnated with mineral bitumen in variable proportions. That which may be used for paving purposes should not contain less than 7 per cent. or more than 12 per cent. of bitumen, as in the former case it would be too

brittle and liable to crack, and in the latter too soft and liable to the action of the heat of the sun.

It is evident that if a sound and solid foundation of first-rate concrete is necessary for carriageways paved with granite setts or wood blocks, it is still more essential that a thin veneer or carpet of asphalte only about 2in. thick will require the same support, and consequently this description of pavement must have the same sort of foundation already described. The method of laying the asphalte upon the surface of the concrete should be executed in the following manner :

The natural rock from an approved mine is first crushed into pieces about the size of walnuts; it is then pulverised in a disintegrator until it is reduced to a fine powder which will pass through a sieve with a mesh equal to 0·10 of an inch. This powder is then heated up to between 250 and 270 degrees Fahrenheit in cylinders, which are kept revolving, so that each particle may become heated without calcining, and still remain separate from its neighbour. The powder is then transported to the street where it is to be laid, in iron-covered carts, in order that it may not lose more than 20deg. of heat during transit, and thus ensure that it will adhere under compression.

The powder is then spread upon the concrete in an even layer, about 3in. in depth, and carefully raked so as to have regularity of depth and surface. Great care must be exercised to ensure that the face of the concrete shall be perfectly dry before the asphalte powder is laid on it, otherwise the moisture is sucked up into the powder, turned into steam, which tries to

escape through the heated powder, and fissures are formed, which may not appear until after the roadway has been made some little time. Such a result will lead to the disintegration of the mass, with the consequence that the material breaks up.

After the powder has been laid and raked, it must be well rammed with iron punners, weighing about 10lb., heated so as to prevent the adhesion of the powder. This ramming must be done lightly at first so as to ensure equality of thickness, and afterwards augmented to heavy blows. After being thus rammed, the pavement must be smoothed by a suitable curved hot iron tool, after which it is again vigorously rammed and rolled until it is quite cool. The roller weighs about 1,100lb., and the finished asphalte is thus compressed to a thickness of about 2in.

Within a few hours of the completed compression of the asphalte, the road is ready for traffic, a light sprinkling of sand being first applied to its surface.

Where asphalte is laid in streets in which there are tram lines, it is found inexpedient to lay it close to the rails. It is better to pave close up to the rails with granite or syenite setts, specially dressed, wedge shape, so as to get them close to the rail and leave the outer course "dog-toothed." The sketch (Fig. 27) of this method is self-explanatory.

As a carriageway pavement, asphalte is pre-eminent in its sanitary qualifications — perfectly impervious, without joints; and with its smooth surface it is not only impervious to moisture and dries quickly, but is easily and readily cleansed, and even washed, and when thus kept carefully clean it is rendered less

Isaacs's paper on "Carriageway Pavements for Large Cities," to which reference has already been made, appears the following with reference to the asphalte streets of Berlin: "The main streets (asphalte) are thoroughly washed and cleansed every morning by gangs of cleaners. During the day the men and boys work singly, but should a good shower of rain fall, they immediately assemble, and make use of the opportunity to wash and clean the streets again. Owing to the general dryness of the climate, the asphalte is less slippery here than in London. Fogs are quite unknown. Snow, of course, is very troublesome on the asphalte. Asphalte is certainly the favourite paving; and one hundred petitions to the Town Council from the inhabitants of one hundred streets asking for asphalte, is nothing unusual in the course of a year. This speaks for itself, and needs no comment."

Major Isaacs also says with regard to the power of asphalte to resist compression, that "during the erection of the additional post office in St. Martin's-le-Grand, a block of granite, weighing $17\frac{1}{2}$ tons, carried on a trolley weighing three tons, or, in all, $20\frac{1}{2}$ tons, equal to $5\frac{1}{8}$ tons per wheel, passed over some asphalte pavement without making the slightest impression thereon."

He also states with regard to its durability that Cheapside and Poultry were laid in 1870 with asphalte, and kept open to traffic without intermission for eighteen years, and Threadneedle-street for twenty-four years; and Mr. Bridgman, the then chairman of the Commissioners of City Sewers, con-

firmed these statements, the asphalte being $2\frac{1}{4}$ in. thick, laid upon 6in. of concrete.

Compressed asphalte as a pavement for carriage-ways has much to recommend it on gradients no steeper than 1 in 60, but the English climate is against it. Where it is possible, however, to keep it scrupulously clean, its slippery surface is much reduced. Some remarks will be made later on with regard to its comparative merits and demerits, with other descriptions of pavements, and it will be seen that it compares very favourably with all other pavements in all the essentials, except one, of first-class carriageway pavements.

BRICK PAVEMENTS.

Brick pavements have not been much used in this country as carriageway pavements, though they have been at one time somewhat largely used for footwalks, but in America and some other countries, notably Holland, they are fairly considerably used—what are known as “vitrified bricks” being principally employed for this purpose; and in a paper read before the Association of Ontario Land Surveyors by J. W. Tyrrill the author states that for ordinary traffic “of, say, five hundred vehicles per yard of width per day and less, a good quality of vitrified brick pavement should give excellent results, and be preferable to asphalte.”

In the city of Liverpool “Tees scorix” bricks from Middlesbrough were laid as a trial in the year 1881. They were not very successful, as they wore very unevenly, and it was found on examination that some of them had large holes in them where the materials had not fused together, and their surface had the further disadvantage of being very slippery—almost like glass. Ordinary bricks might be used for carriageway pavements in exceptional circumstances where other materials were not easily procurable; and if so, they should be laid on edge, with their joints grouted in cement or bitumen, on a proper concrete foundation. Such a pavement, how-

ever, would probably wear very unevenly, owing to the varying quality of the bricks.

In San Francisco a new street pavement has been tried, but with what result the author is unable to state; it is called "hydro-carbolised brick pavement," and consists of bricks boiled in coal tar, which, it is *said*, renders them tough and hard. On the prepared bed a layer of bricks is placed flat, and on this another course of bricks, placed on edge, close together. The interstices are then filled with boiling tar, and the whole covered with a thin layer of screened gravel.

In Des Moines town there are about 10 miles of streets paved with bricks somewhat in the same style, but without any previous tar boiling; it is also stated that bricks are used in West Virginia with good results.

Cleveland and Philadelphia have about 70 miles of brick pavement, and in Wheeling Johnstown, Indianapolis, Baltimore, etc., they are largely used.

In Charleston a brick pavement has been down for twenty years, consisting of vitrified brick laid upon a "9in. bed of fine gravel covered by 2in. of clean bar sand. As the joints are laid close and filled with cement it makes an impervious covering at a low cost, and provides a good wearing surface when the bricks are of good quality."*

In Holland, brick pavements have been used for many years. The road from Utrecht to Conninghem, 27 miles in length, is thus paved, and there are many miles of brick pavement in Rotterdam. It is possible that there may be a field in the future for

* "A Study of Street Pavements," by Lewis M. Hampt, a lecture delivered before the Franklin Institute, November 8, 1889.

bricks of suitable material laid upon a good concrete bed as a material for paving carriageways of light traffic, but at present they cannot compete in this country with either asphalte, granite, or wood.

Before closing these remarks on brick pavements, a few words are necessary on McDougall's patent "combination sett pavement," which consists of a highly vitrified blue paving brick, 10in. by $4\frac{1}{2}$ in. by 5in. deep,

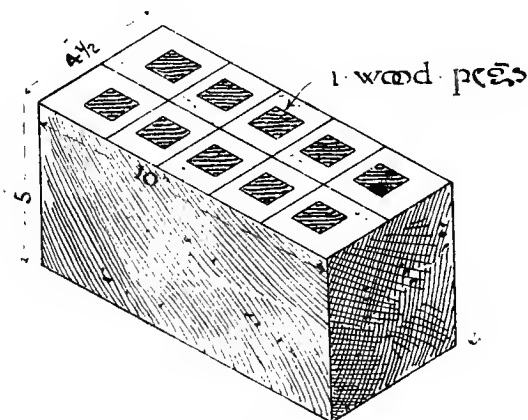


FIG. 28.

made under pressure, and with recesses in it into which are driven square wooden plugs, 2in. long by 1in. square; these plugs are previously creosoted, and it is contended that they always keep about $\frac{1}{16}$ in. above the surface of the brick. It is claimed by the inventor that this description of pavement is silent, durable, non-slippery, non-absorbent, and cheap, and that it wears evenly, and is easily handled and laid, and less costly in transit, as 40 square yards of this

pavement only weighs $6\frac{1}{2}$ tons. The bricks are of the shape shown in Fig. 28. They are laid on a concrete foundation with close joints, grouted in with hot pitch or a bituminous mixture similar to that described for ordinary sett pavements.

The author understands that this description of pavement has been laid at Preston, Manchester, Oxford, Southport, and other places.

SUNDRY MATERIALS.

Various materials have been tried from time to time with which to pave roadways under special conditions—cast-iron plates, which, though ribbed or corrugated, soon wear dangerously slippery; special cast-iron frames with compartments filled with concrete; concrete blocks in the shape of setts; and a great number of artificial asphaltes, all of which, however, have so far proved failures.

More recently we have Elli's wood paving, of which the following is a description: "Excavate the ground 11in. deep, lay broken stones or gravel 6in. deep, well ramming same so as to form the proper camber of the street, with a layer of sand $\frac{3}{4}$ in. deep on top, then place the oak pegs, which are 4in. long and from 2in. to 4in. in diameter, fill up interstices with sand and a small quantity of water, well ram same, sand again and ram until an even and solid surface is produced." Fig. 29 is an isometrical sketch of this pavement.

The objections to such a form of pavement are obvious: it has no homogeneity, and if disturbed would collapse into the trench. It has been tried at Bristol, where, in addition to the above objections, it was found that the sand worked up between the pegs and that the pegs gave way, resulting in an uneven surface.

Indiarubber in large sheets about lin. in thickness has been tried at Hanover on carriageways, and is

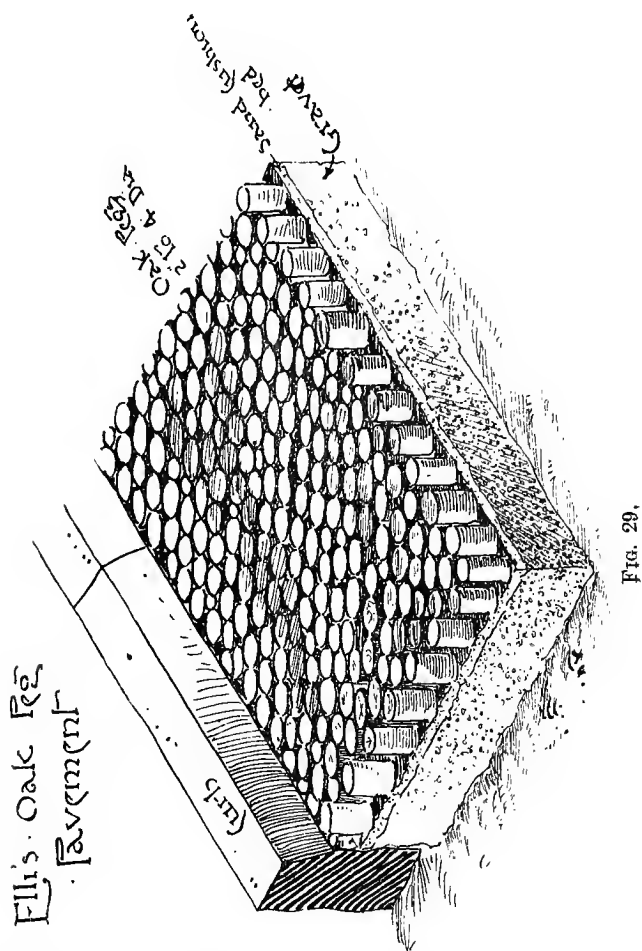


FIG. 29.

said to be an excellent pavement, and no doubt if not too costly it meets nearly all the requirements of

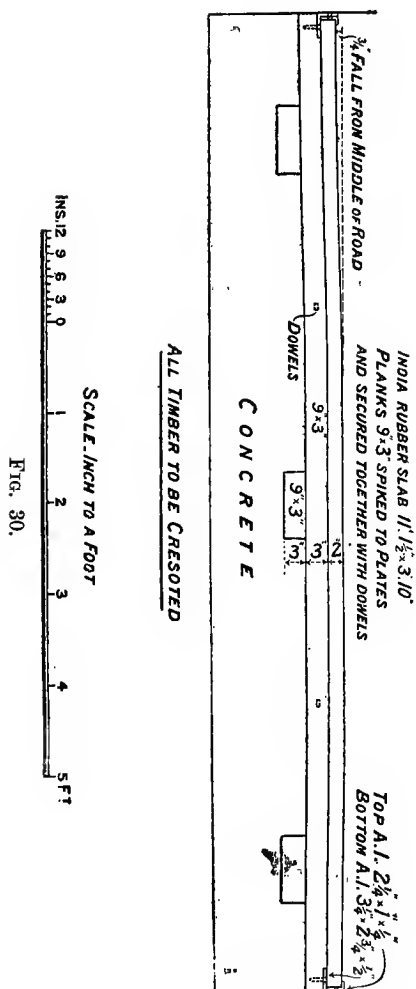


FIG. 30.

a perfect roadway. A small sample of this description of pavement has been laid for many years at the entrance to the Euston Station of the London and

North-Western Railway. The sheets are held down at their sides upon a concrete foundation by strips of iron which clasp the edges tight on each side. It seems to be exceedingly durable, perfectly safe, and absolutely noiseless and impervious.

Fig. 30 is a sketch of this indiarubber pavement, for which the author is indebted to Mr. Francis Stevenson, M.Inst.C.E., the chief engineer of the London and North-Western Railway Company.

It appears that this pavement has been laid about fourteen years, during which period only a small portion has been renewed. Its cost, however—about £7 per square yard—would render the general use for such a pavement quite prohibitive.

Lastly, amongst sundry materials, mention must be made of the blocks recently introduced by the Cork Pavement Company, of 32, Great St. Helens, London, E.C., which are made of ground cork pressed into a bituminous mixture, and known as cork pavement. It is claimed for it that it gives absolutely secure foothold for horses or pedestrians in any weather, and is durable, perfectly noiseless, and non-absorbent, and can be made of any size or thickness to suit all purposes, and that as it is elastic, it prevents the breaking of fragile articles falling upon it.

Messrs. Pickford and Co., the celebrated carriers, have had this pavement laid in the exit from their chief City dépôt, and speak very highly of it.

One of the inclined roadways out of the Great Eastern Railway Station, in Liverpool-street, has also been paved with this material, and it has also been laid in Preston, Manchester, and other cities. It is

laid, in a similar manner to wood pavement, on a concrete foundation.

The author has tested these blocks for absorption and found them practically impervious ; he has no experience, however, of their wearing capabilities, or of their resistance to heavy traffic.

CONCLUSIONS.

Notwithstanding all that has been written and said upon carriageway pavements, and the accumulated experience of many years, it is not an easy question to decide as to what is the best material to use for this purpose which will meet all conditions and requirements. The author has endeavoured to point out that much depends upon local surroundings, such as description and quantity of traffic, the rateable value of the district, available materials, local opinion (though this may often be quite wrong), physical conditions and even climate, width and gradient of the carriageways, the class of property abutting on the streets, and many other considerations which will occur to the officer who is responsible for the condition of the carriageways.

The foregoing pages may be of some assistance in the matter ; but, in order to obtain the opinion of others upon this debatable and interesting subject, the author addressed some questions to the engineers and surveyors of about eighty towns and metropolitan districts, and he has tabulated the replies he has received, and begs most heartily to thank those gentlemen who were good enough to respond to him, and he feels sure that his readers will do the same when they carefully peruse the tabulated return of information annexed.

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

Name of Town.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other Des- criptions, excluding Macadam.
BATH	None. (About two miles pen- nant sandstone pitching.)	2½ miles Arch- angel redwood.	None.	None.
BIRMINGHAM...	23 miles wholly paved and 5½ miles partially paved on tram- way routes.	6 miles wholly paved and 4½ miles partially paved on tram- way routes; creos- oted yellow deal blocks, 8in. long by 3in. wide and 6in. deep.	None.	None.
BLACKBURN ...	Granite, 1 mile ; other setts, about 50 miles.	None.	None.	None.
BRADFORD	77⅔ miles.	526 lineal yards best St. Peters- burg redwood.	About 2 miles.	—

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2. Description of Foundation.	3. Means Adopted to Pre- vent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Condi- tions of Traffic, etc.
For wood, 6in. ground lime concrete and 2in. of cement floating; for pennant, no special foundation.	Coarse sand is spread over wood paving as necessary.	Wood paving gives best satisfaction, owing to its noiselessness prin- cipally. Traffic is not great. Macadam largely used owing to severe gradients.
Portland cement con- crete 6in. thick.	Frequent cleansing and spreading of grit.	In suburban streets, or where the traffic is not too heavy, macadam; in the manufacturing portions, and where traffic is very heavy, granite; in best class of streets, in centre of town, where principal retail shops are found, wood.
For granite setts, 6in. cement concrete; for other setts, 12in. hand- pitched stone under- bedding, consolidated by 15-ton steam-roller.	Watering in dry weather and sanding in the winter.	Granite on concrete for heavy-traffic streets; other setts on hand- pitched stone under- bedding for ordinary streets. Macadamised roads for outskirts of town.
Lias lime concrete made in proportions of 5 to 1.	Granite pavement, watered and sanded; wood pavement, sanded when necessary.	Streets of Bradford are steep; therefore wood and asphalt can only be used in a very few streets. Dalbeattie gra- nite or Yorkshire stone on steeper gradients, and Mountsorrel granite on flatter streets.

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

Name of Town.	1. Length of Carriageways Paved With—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
BELFAST.....	About 11 miles.	None.	None.	About 80 miles peb- ble pave- ments.
BOLTON	About 90 miles.	Beech, 6in. by 3in., about 111 lineal yards; red- wood, 6in. by 3in., about 112 lineal yards.	None.	—
BRISTOL	50 miles.	3½ miles, princi- pally Swedish red blocks, one short length of Karri- wood, and one of creosoted beech.	None.	None.
BURNLEY	Granite, 9 miles ; local grit, 41 miles.	—	—	—
CARDIFF	About ½ mile.	About ¼ mile yellow deal.	About ⅔ mile.	—

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2. Description of Foundation.	3. Means Adopted to Pre- vent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Condi- tions of Traffic, etc.
9in. Portland cement concrete under setts, and 9in. stone pitching under all others.	None as a rule. In some special cases have been ordered to use gravel and sand, but prefer water and good scavenging.	Carnarvonshire setts, as being the least costly, and macadam for safety.
In heavy-traffic streets and under wood pavement, concrete foundation 6in. thick.	Granite setts sanded; wood pavement sprinkled with small granite chippings.	—
Cement concrete.	Scattering fine sharp grit.	Wood is very popular, and will be considerably extended. For heavy traffic one of the harder woods will be used. Granite setts get very slippery on our steep gradients.
Cement concrete for granite sett paving; rubble and ballast for local sett paving.	Either gravel or fine ashes as necessity arises in frosty weather. Narrow-gauge setts are used for steep gradients.	Granite sett paving for streets under heavy traffic, and local grit sett paving for streets under ordinary traffic. Macadam only for residential districts.
Cement concrete 6in. thick.	Frequent scavenging and sanding streets in damp weather.	Asphalte when there are no tramways; but where there are tramways and noise not serious objection, granite paving.

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

Name of Town.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
CARLISLE	About 28 miles Dalbeattie granite and Threlkeldsyenite setts and 4 in. whinstone cubes, the Threlkeld setts being used for steep gradients, and the Dalbeattie and whinstone cubes for flatter streets, the latter in streets with small traffic.	200 square yards beech wood blocks.	—	—
DERBY	2 miles.	$\frac{3}{4}$ mile.	$\frac{1}{2}$ mile.	—
EDINBURGH ...	73 miles.	1 mile creosoted beech.	—	$1\frac{1}{4}$ miles cement concrete.
GLASGOW	153 miles.	$\frac{1}{2}$ mile.	—	—
HUDDERSFIELD	$4\frac{1}{2}$ miles of granite, 30 miles (approximate) local gritstone.	600 yards red-wood with Australian hardwood next tram lines each side of rail.	300 yards Mount-sorrel granite.	—

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2. Description of Foundation.	3. Means Adopted to Prevent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Conditions of Traffic, etc.
Setts and cubes are bedded in sand upon 3in. of gravel, screened to lin. mesh, if the bottom is good; if not, 6in. to 12in. gravel, rolled. Beechwood blocks bedded on lin. of sand laid on 6in. cement concrete foundation. Each course has 3in. soft wood slip lin. deep laid between joints run with bitumen.	Streets flat as a rule. Fine gravel used for a time, but discontinued because attrition caused by traffic made stones more polished and slippery than before.	Coarse-grained gravel or syenite setts 6in. by 3in. laid close on a thoroughly hard foundation, and jointed in bitumen. Stones from Threlkeld quarries give most satisfaction, as they apparently do not wear so round at the edges and are less slippery than other kinds used here.
6in. to a foot of Portland cement or lime concrete, with ½ in. sand bedding.	Sanding when necessary.	Wood paving with Baltic redwood blocks, creosoted and grouted with boiling pitch and racked up with pea gravel.
6in. Portland cement concrete.	Sprinkling of fine gravel.	Granite, whinstone, wood, macadam (in different situations).
Concrete from 4in. to 6in. thick.	Sanding when necessary.	Granite and whinstone setts, 3½ in. broad on head, and from 6in. to 7in. deep.
Chiefly cement concrete from 6in. to 9in. thick, about 4½ parts stone to 1 cement.	Sanding both granite and wood where needed.	Granite setts for heavy traffic; gritstone for severe gradients or light traffic.

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

Name of Town.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
HULL	About 15 miles granite setts.	About 1½ miles creosoted red- wood.	—	A few miles of cobbles; gradually being re- placed by granite.
IPSWICH	None.	2 miles creosoted fir.	—	—
LEICESTER	72 miles, 815 yards.	459 yards Jarrah wood, 324 yards uncreosoted red deal.	—	—
LINCOLN	6 miles, 1,106 yards.	214 yards of 9in. by 4½in. red deal.	260 yards pitch and tar mac- adam.	—
MANCHESTER...	621 miles.	1 mile of Jarrah, Karri, and pre- served beech.	None.	About 230 yards of patent pavements.

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2. Description of Foundations.	3. Means Adopted to Prevent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Conditions of Traffic, etc.
For granite, 7 to 1 cement concrete 7in. thick; for wood, 6 to 1 ditto brought to a smooth face with cement 3 to 1.	Wood paving sprinkled daily with fine gritty gravel, small stones of which become embedded.	Where noise is not an objection, well-dressed granite setts, but wood is a luxury well worth paying for in certain cases.
3in. Portland cement concrete; proportions: clean shingle 5, sharp sand 1, cement 1	Watered and swept when necessary. In frosty weather fine shingle or coarse grit sand is sprinkled.	Creosoted wood blocks. Australian wood is too hard, the price double, but questioned whether it will wear twice the time.
6in. cement concrete for wood and granite paved streets.	Thorough scavenging of wood pavements by street orderly boys, and by sanding or graveling when requisite.	3in. by 5in. granite setts, grouted up with pitch and tar.
Portland cement concrete 6in. thick.	Spreading small gravel whenever weather demands it.	Prefer wood in centre of city only, and on level roads; otherwise 5in. by 3in. granite setts on concrete bed, run in with pitch, tar, and creosote.
In new streets, etc., 10in. furnace cinders, or other hard materials, properly broken, and 2in. of gravel passed through riddle of 1½in mesh on top. Wood pavements, 6in. Portland cement concrete; in some cases have gone 12in. deep.	Both granite and wood pavements are cleansed, watered, and sanded.	Pavements almost wholly of granite; during the past year about 8,000 square yards of wood pavement have been laid solely on account of its comparative noiselessness.

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

Name of Town.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
LIVERPOOL.. ...	141 miles.	2½ miles English elm, beech, Canadian red pine, American pitch pine, and Baltic red wood.	2 miles.	109 miles boulders, etc.
NEWCASTLE UPON-TYNE.	118½ miles, partly setts and partly "chips" or "randoms."	Perhaps ¾ mile, chiefly creosoted beech. Experimental pieces of Jarrah, Karri, etc.	—	Some whin, but not used except where streets are flat.
NORWICH	About 3 miles.	About 7 miles, mostly red Baltic or Memel, creosoted.	—	—
NOTTINGHAM...	Granite 90 miles.	3 miles red deal, creosoted and uncreosoted, pitch pine, Jarrah, and creosoted beech. The latter is quite a failure.	—	Many miles of tar macadam.

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN
THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2 Description of Foundation.	3. Means Adopted to Pre- vent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Condi- tions of Traffic, etc.
Portland cement concrete, not less than 6in thick in streets of heavy traffic, and 5in. in streets of light traffic, and in residential streets of little traffic and pitched rock	Fine gravel is spread.	Welsh syenite setts.
For paving of all kinds, 8in. pinning in all cases (Telfordising); for wood, 6in. cement concrete. Sand or ashes to pave on lin. or 2in. thick.	Sanding in paved streets. Small pea or granite gravel on wood. Embeds and makes excellent top.	Granite setts are dear but last longest, therefore cheapest in the end. "Chips" in suburban streets last many years with little repair. Wood is less noisy but very dear, and lasts only half the time of granite, say 10 or 12 years.
Chiefly upon a sand bed on such old foundations as exist. Small part has 6in. cement concrete foundation.	Sanding (water dear).	Wood in busy retail, etc., streets. Granite in busy streets through manufacturing districts. Contemplate introducing a considerable amount of tar macadam of iron slag, or hard blue mountain limestone and gas tar boiled until stiff, in suburban roads.
For sett and wood paving, 8in. thick cement concrete.	All main thoroughfares are sanded, some every day, others as often as necessary.	Heavy - traffic streets, the cheapest is granite sett paving on a concrete foundation; the safest, excepting macadam, is wood.

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

Name of Town.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
PORTSMOUTH...	None.	None.	1,100.	—
PRESTON.....	About 15 miles.	—	—	About 60 miles boul- ders.
SALFORD.....	About 143 $\frac{3}{4}$ miles.	About 100 yards red deal wood.	—	About $\frac{1}{2}$ mile mac- adam, run in with pitch.
SUNDERLAND...	About 3 miles	About 2 $\frac{1}{4}$ miles	None.	Whinstone random setts on ballast. (All pri- vate street work, and several miles of public streets). Also whin and ran- dom setts on concrete foundation and granite random setts on on concrete and on ballast.

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN
THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2. Description of Foundation.	3. Means Adopted to Pre- vent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Condi- tions of Traffic, etc.
Portland cement con- crete 6in. thick.	Spreading of small shin- gle in frosty weather.	Have only asphalte, and strongly advises com- mittee to have more laid down.
Rubble stone 8in. thick.	None.	Granite setts. Dalbeat- tie preferred to all others.
Light - traffic streets, 12in. of ballast. Heavy- traffic streets, 18in. rubble pitching.	Sanding by centrifugal distributing carts.	Where gradients are not too steep, Penmaeu- mawr setts. Steep gra- dients softer granite used, but does not last long.
For wood and granite in heavy-traffic streets Portland cement (6 to 1) 6in. thick.	Sanding with a distri- butor; sometimes gravelling. Fine gravel rolled into surface of wood paving.	Granite setts where noise is not a serious objection. Memel tim- ber, creosoted, in busi- ness streets where quiet is a matter of importance.

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

Name of Town	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
SHEFFIELD.....	Granite, 20·28 miles; gritstone, 19·95 miles.	0·41 mile, chiefly deals; no hard- woods.	None.	Boulders (small grit setts) 47·63 miles.
SOUTHAMPTON.	None.	None.	680 yards	—
WEST BROM- WICH.	8½ miles of tram- way paved with Leicestershire granite setts grouted with pitch.	—	—	—
WOLVERHAMPTON.	Are now paving some busy streets with granite setts.			
YORK	Not kept sepa- rate.	2 miles, 2 fur- longs, 2 perches creosoted red deal.	About 1 mile.	About 12 miles.

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN
THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2. Description of Foundation.	3. Means Adopted to Pre- vent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Condi- tions of Traffic, etc.
For granite and wood, concrete; for gritstone, a bed of slag shingle; for boulders, ashes.	Watering and shingling with granite chips.	Where not too steep, granite or concrete. Steep gradients are paved with gritstone and macadam, though extra cost of repairs and maintenance is very great.
6in. cement concrete.	Kept thoroughly scavenged and sanded in frosty weather.	In the principal tho- roughfares, where the paving is most required, the crossfall is too great for wood block paving, which, under existing conditions, would be preferred.
6in. concrete.	None.	Granite or hardwood.
6in. cement concrete and asphalte grouting.	—	—
For sett and wood paving, 6in. cement concrete 5 to 1.	Coarse sand; whinstone screenings on wood only.	Well-dressed granite setts for heavy traffic; wood for streets with good shops abutting; tar macadam for sub- urban roads; second quality granite setts for secondary streets and back roads.

METROPOLITAN

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

District.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
BERMONDSEY...	About 16 miles.	About $\frac{1}{2}$ mile, deal; shortly in- tend laying hard- woods and as- phalte.	—	—
CAMBERWELL.	About 4 miles.	None yet.	None.	None.
CHELSEA... ..	—	$\frac{1}{4}$ miles, 763 yards deal, and small length of Karri.	1,078 yards	—
GREENWICH ...	About 4 miles.	About $\frac{1}{2}$ mile pitch pine, yel- low deal, and Jarrah.	None.	Have tried a small portion of patent cork pav- ing, but traffic by the side of tram lines is too great and cut- ting for it.

DISTRICTS.**DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN THE SUBJECT OF CARRIAGEWAY PAVEMENTS.**

2. Description of Foundation.	3. Means Adopted to Prevent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Conditions of Traffic, etc.
Thames ballast and Portland cement; thickness depends on traffic.	Sprinkling with shingle.	Heavy traffic, granite setts; thickly-populated districts and narrow streets, asphalt; where noise is an important consideration, wood; residential parts, macadam.
For granite setts, 6in. concrete; for macadam, 12in. hardcore properly formed and rolled.	Sanding on hills, and in slippery weather roads generally.	Granite setts in main roads with heavy traffic; granite macadam in other roads with heavy traffic; flint in other roads; ragstone for steep gradients. Prefer asphalt or wood for cleanliness.
Portland cement concrete.	Strew sand or ballast on slippery roads. Wood pavement is frequently washed.	No steep gradients in parish. Yellow deal in principal streets; just making trial of asphalt. Hardwood pavements are undoubtedly a success.
Best blue ground lias lime and Thames ballast about 6in. thick.	Keep surface as clean as possible, and use sharp sand.	For economy, granite setts are best where trams exist, but greater part of district macadam, Kentish pit flints, and ragstone.

**TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON**

District.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
FULHAM	About 100 lineal yards.	About 4½ miles in all ; ¾ mile plain yellow deals, 3¾ miles ditto creos- oted. About 100 yards of Jarrah.	310 lineal yards.	—
HAMMERSMITH	730ft. run 6in. by 3in. granite setts.	Yellow deal. 12,358 sup. yards; Jarrah, 13,957 sup. yards; beech, 4,198 sup. yards.	None.	—
HOLBORN	9 miles, 1,066 yards.	1 mile, 358 yards, yellow deal blocks	2 miles, 406 yards.	—
KENSINGTON ...	9,155 yards granite.	196,314 square yards.	—	—
MILE END OLD TOWN	5½ miles.	None.	None.	—

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2. Description of Foundation.	3. Means Adopted to Pre- vent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Condi- tions of Traffic, etc.
6in. Portland cement concrete, 6 parts clean Thames ballast to 1 part cement.	Sand in frosty and greasy weather.	Creosoted yellow deal blocks, 9in. by 5in. by 3in., with 10lb. creosote to each cubic foot tim- ber, forced in by pres- sure.
6in. Portland cement concrete.	—	Jarrah paving and creos- oted yellow deal
6in. Portland cement concrete.	Keep surface constantly clean, first by washing when necessary, and afterwards by using fine grit.	Asphalte.
Concrete.	Wood pavements washed and swept daily, other principal tho- roughfares not less than twice a week. Various kinds of sand grit and crushed shingle to suit snow, frost, and ice, and varying road surface.	That which we have laid down.
Portland cement con- crete.	Covering of clean sharp hoggin.	Sharp hoggin, granite for main roads and heavy traffic, macadam for ordinary streets, asphalte for small back neighbourhoods occu- pied by dirty class of people.

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

District.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
LAMBETH	1 $\frac{1}{2}$ miles of granite setts.	1 $\frac{1}{2}$ miles of deal blocks and 6 $\frac{1}{4}$ miles Jarrah.	None.	—
NEWINGTON ...	3 $\frac{1}{2}$ miles.	About $\frac{1}{2}$ mile cre- soted deal.	About $\frac{1}{4}$ mile.	None.
PADDINGTON ...	Public roads, 1 furlong, 166 yards; mews, 6 miles, 212 yards.	8 miles, 135 yards, 3in. by 9in. by 6in. best Baltic tim- ber.	—	—
PLUMSTEAD ...	About 2 miles.	—	—	—
ST. GEORGE'S- IN-THE-EAST	About 14 miles.	—	—	—
ST. GILES	About 9 miles, or 87,000 yards super.	$\frac{3}{4}$ mile, or 14,000 yards super, deal, Karrī, and Jarrah.	6 miles, or about 95,000 yards super.	—

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2. Description of Foundation.	3. Means Adopted to Pre- vent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Condi- tions of Traffic, etc.
Portland cement con- crete 6in. thick.	Cleansing and sanding.	Western Australian woods Karri and Jarrah where traffic is heavy and gradients fairly level, as here.
Portland cement con- crete.	Thames or other sharp sand strewn over the surface.	Selected Australian hardwoods for principal thoroughfares, and as- phalte for courts, alleys, and narrow streets on sanitary grounds.
6in. Portland cement concrete.	Spreading fine shingle.	Fine Thames shingle for wood and granite paved roads, and fine hoggin for macadam, gravel, or flint roads.
Portland cement con- crete with lin. of sand on top.	Sand, etc.	Granite and wood pav- ing.
9in. cement concrete.	—	3in. by 7in. Aberdeen granite pitchings.
For granite, concrete composed of blue lias lime and ballast 1 to 6; for wood and asphalte, Portland cement and ballast 1 to 6.	Keeping paving as clean as possible by scraping and washing. Bins, containing fine screened Thames ballast or shell ballast, are placed along wood or asphalte roads to be used occasionally, mainly to assist horses to rise after a fall.	In all cases where granite pavement wears out asphalte is substi- tuted, and in several instances wood has been removed and asphalte laid down where gra- dients were less than 1 in 60.

**TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON**

District.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
ST. GEORGE, H A N O V E R S Q U A R E	About 5 miles.	About 12 miles creosoted 6in. deal.	2 miles.	—
ST. JAMES, WESTMINSTER	$\frac{3}{4}$ mile.	$3\frac{1}{2}$ miles yellow deal, Jarrah, and Karri.	$5\frac{1}{4}$ miles French asphalte.	—
ST. JOHN, HAMPSTEAD	Not more than $\frac{1}{2}$ a mile.	1 mile, 2 furlongs, of which 7 fur- longs are Baltic fir and 3 furlongs Jarrahdale Jar- rah.	—	—
ST. LEONARD, SHOREDITCH	About 15 miles.	About $\frac{1}{4}$ mile creosoted yellow deal blocks.	About 1 mile of compressed Val de Travers.	—
ST. MARTIN-IN- THE - FIELDS, WESTMINSTER	1 mile, or 9,100 square yards	$3\frac{3}{4}$ miles, or 75,830 square yards, creosoted deal.	1 mile, or 9,341 sq. yards, Val de Travers	—
ST. MARY, IS- LINGTON	12 miles.	$\frac{1}{2}$ mile Jarrah, Karri, and yellow deal.	$\frac{1}{2}$ mile.	—

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

2. Description of Foundation.	3. Means Adopted to Prevent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Conditions of Traffic, etc.
Portland cement concrete.	Well strewn with ballast when necessary. In frosty weather, or when pavement is greasy, crushed ballast as good as anything.	—
Portland cement concrete.	On wood and granite, sand and ballast is used; on asphalt, cockle shell.	Wood and asphalt.
6in. Portland cement concrete.	Sprinkling granite siftings.	Macadam.
Portland cement concrete.	Main thoroughfares swept daily, and minor thoroughfares about twice a week, washing and sanding when required.	Guernsey granite pitching for main thoroughfares; compressed asphalt for minor streets.
Cement concrete 6in., 6 to 1 by measure for wood, 8in., and asphalt 6in.; 8in. lime concrete for granite.	Sprinkling with $\frac{1}{2}$ in. ballast. Cleansing, however, is now hywashing, which is a better prevention against any slipperiness.	Wood for gradients, and asphalt for level streets.
Portland cement concrete in paved roads, brick rubbish in all others.	Frequent washing.	For heavy traffic, granite or hardwood is most suitable; for lighter traffic macadam.

TABULATED RETURN OF INFORMATION RECEIVED FROM
REPLY TO QUESTIONS ADDRESSED TO THEM ON

District.	1. Length of Carriageways Paved with—			
	A. Granite or other Setts.	B. Wood.	C. Asphalte.	D. Other De- scriptions, excluding Macadam.
ST. MARY, BATHURSEA	Principally flint and macadam, granite setts for tramway track.			
ST. OLAVE.....	Granite pitching only.	4,326 super yards wood.	—	—
WESTMINSTER	—	135,500 super yards dipped deal blocks.	48,055 sup. yards.	—
WHITECHAPEL	18 miles.	Jarrahdale in front of London Hospital ; wood in front of infirmary and some of the churches and schools.	About $\frac{1}{2}$ mile.	—
WOOLWICH ...	About 2 miles.	—	—	—

DIFFERENT TOWNS AND METROPOLITAN DISTRICTS IN
THE SUBJECT OF CARRIAGEWAY PAVEMENTS.

3. Description of Foundation.	3. Means Adopted to Pre- vent Slipperiness.	4. Opinion as to the Best Available Covering for the Carriageways of the Respective Towns under Local Condi- tions of Traffic, etc.
—	In frosty weather four of Glover's patent sand- ing machines, with sharp sand or fine ashes from dust depôt.	—
Portland cement con- crete.	Crushed ballast on all carriageway paving.	Crushed ballast, speci- ally screened, found the best.
6in. Portland cement concrete.	Sand in frosty weather.	Wood for main streets ; asphalte for secondary streets.
Mostly Portland cement concrete, but also lias lime concrete.	Gravel is spread in places.	Custom is to lay Aber- deen or Guernsey 3in. by 9in., or 3in. by 7in. granite cubes.
Concrete.	Sanding.	Traffic and gradients vary so much that opportunity is offered for all kinds.

The consensus of experience, practice, and opinion which may be gathered from the foregoing table is exceedingly valuable as a guide to those who are studying the question. Many points are obviously omitted, such as cost, gradients, widths, size of setts or blocks, and many others; but all these are questions more or less of locality, and the replies thereto could not be of any great value.

The question of jointing or grouting material has been settled by Mr. Blair's excellent report on this subject, to which allusion has already been made, and the verdict is strongly in favour of a bituminous or partially elastic material.

From a close study of the theoretical and practical essentials of a good paving material, the author has ventured to prepare the following table, which he

TABLE OF COMPARISON OF MERITS AND OBJECTIONS OF DIFFERENT CLASSES OF PAVEMENTS.

Note.—The numbers refer to order of merit.

Description of Pavement.	Ease of Traction.	Foothold.	Cleanliness.	Noiselessness.	Durability.	Economy.	Facility of Repairs.	Impermeability.	Suitability to all Classes of Traffic.	Suitability to all Gradients.	Uniformity of Wear.	Appearance.
Asphalte	1	4	1	2	2	2	1	1	2	4	2	1
Bricks	2	1	3	3	3	3	3	3	3	1	4	3
Granite.....	4	3	2	4	1	1	2	2	4	2	1	4
Wood	3	2	4	1	4	4	4	4	1	3	3	2

thinks may serve as some guide to those who are in-

vestigating the question as to what is the best pavement to use, always bearing in mind that everyone must be greatly influenced by his own special requirements of local conditions and surroundings.

It will be observed, from the foregoing table, that asphalte is allotted 5 firsts, 5 seconds, no thirds, and 2 fourths; bricks have 2 firsts, 1 second, 8 thirds, and 1 fourth; granite receives 3 firsts, 4 seconds, 1 third, and 4 fourths; wood has 2 firsts, 2 seconds, 3 thirds, and 5 fourths.

This table will probably give rise to much discussion; the advocates of each special paving material probably preferring their own to the others, and the opinions on the life, slipperiness, and other requirements of a good pavement being various and diverse. For instance, in the United States, Captain Green's observations show, with regard to the latter quality, that wood is worst, granite next, and asphalte the best; whereas Colonel Haywood's observations placed them in the following order: granite worst, asphalte next, and wood the best. Mr. Byrne, in his "Treatise on Highway Construction," gives the life of pavements as follows:

Granite block	...	...	12 to 30 years
Sandstone	...	...	6 to 12 ,,
Asphalte	...	...	10 to 14 ,,
Wood	...	...	3 to 7 ,,
Limestone	...	...	1 to 3 ,,
Brick	...	...	5 to (?) ,,

but this can only be speculative, as so much depends upon the class, weight, and concentration of traffic,

and the quality of the materials selected, as well as the method adopted in laying them. It has been shown, for instance, in this book that the life of granite pavement is much longer than that allotted by Mr. Byrne, and experience has also shown that wood blocks of the better hard-wood Australian descriptions have a longer life than the seven years allowed by him.

The life also of a pavement is greatly interfered with by the question as to how often it is disturbed for gas, water, and other purposes; and on this point all those responsible for the good maintenance of carriageways in towns will agree that something ought to be done, if possible, in the way of provision for subways under the street, when it is considered how many causes for disturbance of the surface have accrued with modern requirements. In addition to gas and water, there are now telephone tubes, electric cables, hydraulic pipes, telegraph wires, and even pneumatic tubes, for which provision has to be made under our street surfaces, with disastrous results to the good management of their pavements.

Having thus far concluded the subject of the paving of the carriageways, the author will now proceed to make a few remarks upon

CURBS AND GUTTERS.

Curbs or curbstones are always used for the outer side of all footways, with whatever materials they may be paved, for the following reasons :

- (1) The curb acts as a sill for the raised footway against which the material with which it is paved may butt.
- (2) It retains the foundation and surface of the footwalk.
- (3) It keeps off the vehicular traffic.
- (4) It raises it above the water flowing in the gutter or channel.
- (5) It forms the side of the gutter.
- (6) It is necessary to act as a butt for the haunches of the carriageway.

The materials employed for curbing are the natural stones — such as granite, syenite, sandstone, etc., cement concrete, vitrified fireclay blocks, cast and wrought iron. Granite or syenite, being the best, are generally used in streets where there is much traffic, as the curb is often subjected to severe blows from the passing vehicular traffic, as well as a grinding action from the wheels of wagons and other heavy vehicles, especially on gradients where “ hugging ” the curb acts as a drag or brake. In such cases, granite or syenite, although the most expensive in

the first case, are certainly the most economical, and no other materials should ever be used unless there are some very good reasons for their substitution.

The proper dimensions for this description of curb must naturally vary considerably in different localities and in great measure according to the width of the footways, for it is evident that the wider the footway the wider should be the curb. In any case, however, it must never be of less depth than 9in. nor narrower than 4in.; depth of curb is necessary to keep it from falling over towards the gutter, and width is mainly for appearance and also to allow of the splay, which will presently be explained. The curb should never be in lengths of less than 3ft., and when 8in. and broader, the top surface should be bevelled off to conform to the slope of the footway and allow the water falling on its surface to reach the gutter.

Granite curb should be drafted about 1in. along both top edges, and hammer-dressed about 5in. on the face, in addition to the whole surface of the top and for 3in. at the back, in order that there may be a smooth surface visible against the channel gutter, and also for the flagging or other paving to butt fair against, besides giving a clean appearance to the arris of the curb both inside and out; in addition to this, in streets of heavy traffic it is well to splay off the front face of the curb in order to minimise the effect of the grinding action previously mentioned. Fig. 31 (section of an 8in. granite curb) will explain this.

The top surface of the curb, which is, of course,

fair with the surface of the footway, should always be tooled or axed whenever it has worn slippery, as a slip from a curbstone often causes a bad fall to a pedestrian.

Deep and narrow curb may be bedded on a good bed of gravel and beaten into place with hard blows from a heavy setting maul or beetle, weighing not less than 50lb., the filling in on the gutter side being well rammed with an iron bar to keep the

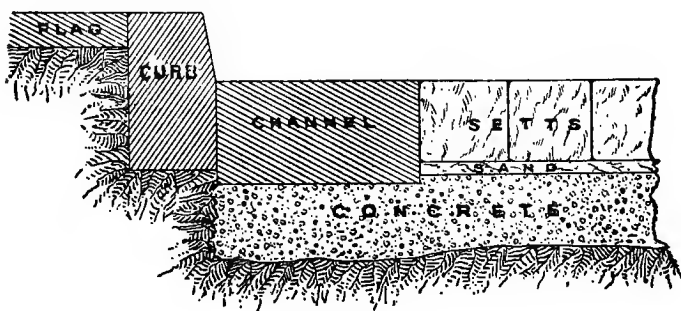


FIG 31.

curb upright and prevent it falling over towards the gutter—a very unsightly and objectionable performance. Broader and shallower curbstones should be bedded on concrete.

The model bye-laws issued by the Local Government Board for the use of sanitary authorities (IV. New Streets and Buildings, 1877) provide that the footway of new streets shall be constructed “so that the height of the curb or outer edge of such footway above the channel of the carriageway (except in the case of crossings paved or otherwise formed for the

use of foot passengers) shall be not less than 3in. at the highest part of such channel, and not more than 7in. at the lowest part of such channel."

The idea of this is that a height of less than 3in. would render it possible for vehicles to drive on to the footways or for the water in the gutter to overflow it, and with a height of more than 7in. it would be inconvenient for foot passengers, and also render the curb liable to tilting over towards the gutter.

Having thus far dealt with curbs made of syenite or granite, the remarks on which equally obtain in great measure to those of other materials, the author will make a few remarks on

Curbs of Cement Concrete.

These can be made either *in situ* or, preferably, in blocks made in moulds, either subjected to hydraulic pressure or simply made by hand.

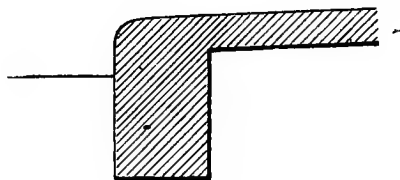


FIG. 32.

In every case, the concrete of which they are made must be carefully compounded of well-selected materials—the best Portland cement (on which the limits of this book will not permit any remarks) and perfectly clean

shingle, sand, ballast, or broken stones in proper proportions, and carefully mixed together. If the footway itself is made of concrete, it may be finished with a concrete curb by means of a plank moulding rigidly

·Fireclay Brick Curb·

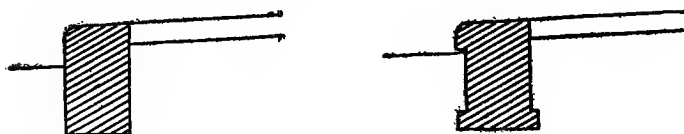


FIG. 33.

fixed in place, so that when removed the curb forms a part of the footway, and has the appearance when finished as shown in Fig. 32.

Concrete curbs made in moulds at the yard, and fixed in a similar manner to granite or other stone

·Fireclay Brick Curb·

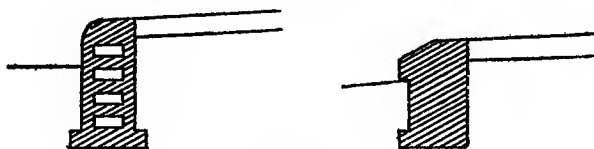


FIG. 34.

curbs, require no explanation; they are, like the concrete curb, made *in situ*, quite suitable for streets of light traffic, but cannot be recommended where they would be subjected to heavy blows or grinding action from the wheels of passing traffic of a heavy character.

Fireclay Brick Curbs

Are not often used in this country, but they have been employed in America with success; they can, of course, be made of almost any shape—those which have hitherto been in use are shown in Figs. 33 and 34.

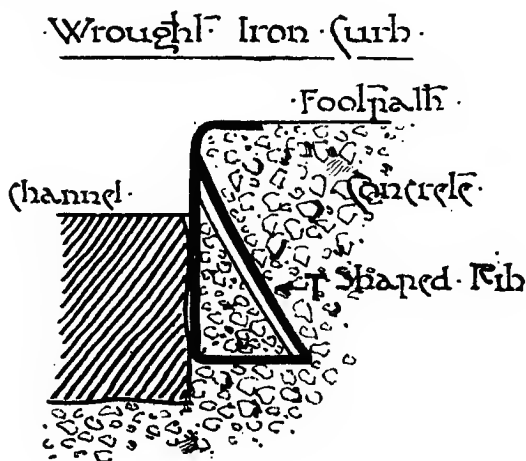


FIG. 35.

Wrought and Cast Iron Curbs

Have been used in France and elsewhere; two examples are given in the accompanying diagrams (Figs. 35 and 36).

Having thus far dealt with the question of curbs, a few remarks are necessary upon

Gutters.

These are also called "channels," "channel gutters,"

or "water tables," and are necessary for carriageways, not only as adding to their appearance, but also to carry the water along the branches of the carriageway, and, in the case of unpaved roads, to prevent the wash of the water undermining the curb and causing it eventually to fall over towards the carriageway.

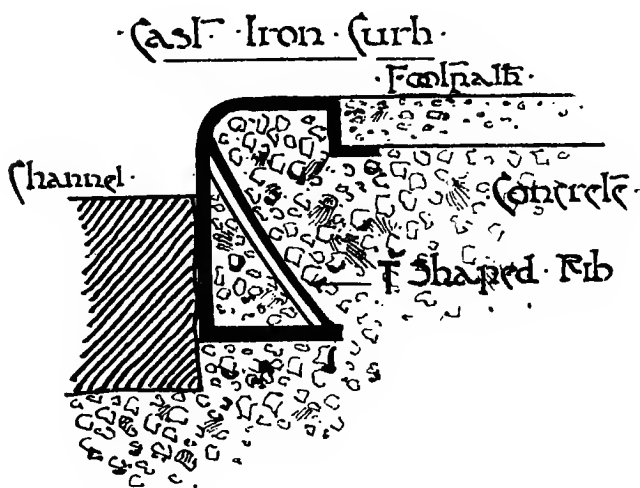


FIG. 36.

In the case of paved streets, with which this book deals, the gutters are usually constructed of the same materials with which the carriageway is paved: thus with granite or syenite paved streets, the gutters are formed of precisely the same setts, only they are placed longitudinally, instead of transversely, so as to aid the flow of water in the channel, which in no case should have a flatter gradient than about 1 in 300, their transverse section sometimes following the contour

of the barrel of the carriageway, and sometimes being nearly level.

A channel gutter should be from 12in. to 18in. wide, so that if the latter, and it is constructed with ordinary 3in. setts, six courses will be necessary. They should be bedded on the concrete foundation of the roadway, and be racked and grouted in the usual manner already described for sett-paved carriageways.

Sometimes granite slabs 12in. or 18in. wide by 3in. or 4in. thick are used, and make an excellent gutter, care being taken to dress their abutting faces perfectly evenly, so that they butt closely together, as otherwise they are liable to tip under heavy loads. The diagrams already given will serve to show these channel gutters, so that no further explanation is necessary. At the crossings or intersections of streets it is well to keep the gutters level with the curb, so that pedestrians may step off the footway on to the crossing without any drop; or if the levels will not permit this and they have to carry water at these points, it is a good plan to let the edge of the crossing drop rather suddenly towards the curb, so that the ordinary stride of the pedestrian carries him on to the level. In some cases, in order to meet this difficulty, iron plates are fixed over the channel, which is made of square section at these points, but this plan is objectionable, as seriously interfering with the vehicular traffic, and cannot, consequently, be recommended.

In connection with the channels it is necessary to have at certain intervals, pits or openings connected with the sewer under the street; these are called

“gully pits” or “catch basins,” and in some cases “buddle holes” or “bunnies.”

The gully pits are, of course, covered by iron gratings, and of such form, materials, and dimensions as the necessities and peculiar circumstances of each case require.

A great number of different forms have been from time to time introduced for this purpose, the principal objects to be considered being as follows:

- (1) Sufficient area of open grating surface to carry off heavy rainstorms.
- (2) Sufficient cubical contents of pit to retain road detritus and mud below the outlet to prevent their being carried by the water into the sewer.
- (3) The grating so constructed that it cannot be easily choked on the surface by leaves, pieces of paper, or other *débris*.
- (4) The least possible obstruction to the traffic.
- (5) So constructed that the pit may be easily cleaned out and the drain unchoked in the event of stoppage occurring.
- (6) A good seal or trap to prevent the escape of sewer gas.

The pit should also be constructed of materials that will not readily be damaged by the scoop or other tool employed for the purpose of removing the mud or grit caught by the pit.

The following diagram (Fig. 37) is a section of the gully pit in use in the City of Liverpool. It is constructed of brickwork lined with cement, with

a bottom of York or other suitable stone flag—the tongue or seal is made of similar stone.

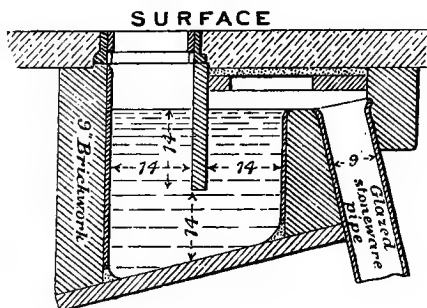


FIG. 37.

The following diagrams give some of the patent gully pits which have been invented and which have various merits, which will be seen by a reference to the drawings :

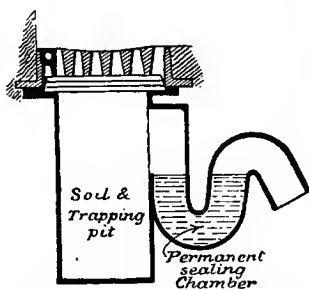


FIG. 38.—Willoughby's Patent Street Gully.

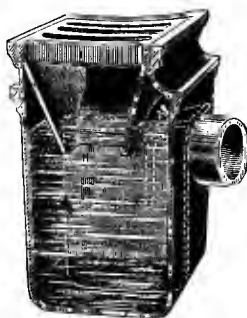


FIG. 39.—Crosta's Patent Surface-Water Gully.

Fig. 41 is a diagram of a "buddle hole," or bunnie, which is simply a pit under the footway covered with a flag, the surface water from the

channel entering sideways into it. The disadvantage of this is the difficulty of cleaning it or clearing the

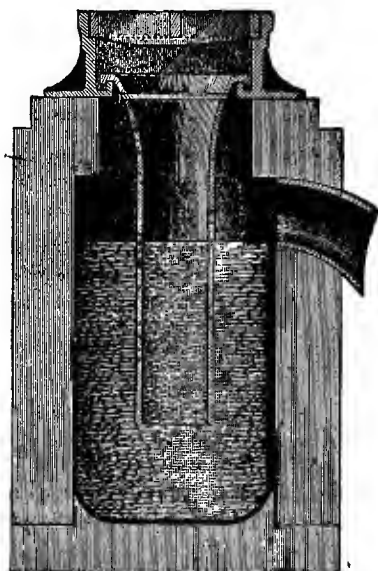


FIG. 40.—Priest's Patent Trapped Gully.

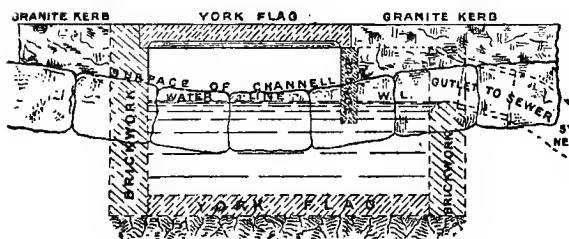


FIG. 41.

syphon or drain leading to the sewer, otherwise this form of gully has much to recommend it.

FOOTWAYS.

Much has been written upon the subject of carriage-ways, but hitherto very little upon footways.

The Romans, who were the earliest roadmakers, did not provide footways, for Bergier, in his "*Histoire des Grands Chemins de l'Empire Romain*," says that these roads had only blocks of stone at the side for foot travellers to rest upon. It is probable, therefore, that the addition of footways to the sides of roadways was by means of a gradual development.

The width of the footway is to some extent regulated by the width of carriageway and by the exigencies of the trade and traffic of the street. Attention has already been called to the generally excessive width of the carriageways in this country in proportion to the footways, and it would be advantageous if the custom in this respect received every consideration before deciding this important question.

The slope of the footway from the heel to the curb depends upon the material which is used for the surface, the object of this slope or fall being, of course, to drain the water which falls upon the footways towards the channel gutter.

For natural stones, about $\frac{1}{4}$ in. to the foot is generally given, but for concrete or asphalt footways $\frac{1}{8}$ in. to the foot is sufficient.

The materials which may be selected for paving the surface of the footway are very various, but the following may be given as embodying most of them which are suitable for urban footways :

- (1) Natural stones, such as Yorkshire and Caithness flagging, etc.
- (2) Natural asphalte, compressed and mastic.
- (3) Concrete in monolith or slabs.
- (4) Bricks or tiles.
- (5) Various compositions.

The requirements for a good material with which to pave footways may be summarised as follows :

- (1) It must be smooth, but not slippery.
- (2) It must be durable and non-abrasive.
- (3) It must absorb the minimum amount of water so that it will dry rapidly after rain.
- (4) It must be easily repaired.
- (5) It should be economical, without sacrificing efficiency.
- (6) It must be strong to resist blows from falling goods, etc.
- (7) It must be of uniform quality so as to wear evenly.
- (8) Its texture should be such that dust and mud will not readily adhere to it.
- (9) Its appearance and colour should not be distasteful.

Many of these requirements can be easily ascertained before the material is selected. Its absorbent powers may be tested by soaking in water and

noticing the difference in weight; its microscopic appearance and specific gravity will give some idea of its quality; the wear may be ascertained by rubbing and drilling with certain defined and regulated pressures. But these observations are not to be compared with the experience gained by actual trial, and consequently the best test is to lay some of the proposed material upon a footway where there is a known amount of traffic, and to note its behaviour under these conditions.

Natural Stones.

Of the natural stones, granite slabs from 3in. to 6in. in thickness are occasionally employed under special circumstances, but the stone most frequently used is either Yorkshire or Caithness flagging. Limestones from various districts are sometimes used, and occasionally slate. With reference to some of these stones, granite, although exceedingly durable and strong, is heavy to handle and in most cases very expensive: it is difficult to work, and in process of time wears dangerously slippery. Outside markets or public buildings where the traffic is considerable, or where heavy packages are liable to be thrown upon it, it may sometimes be adopted with advantage, but from returns which the author obtained a few years ago upon the subject of paving footways from one hundred and thirty-eight English towns, it appeared that in only eight towns granite was used to any extent for this purpose, whereas it is almost universally used for curb. Yorkshire flags, on the con-

trary, were used by eighty-three towns, as they comply with a great many of the essentials of a good footway. They give a capital foothold to the pedestrian, they can be easily taken up, redressed, or turned and reused; such material does not wear slippery and it is easily worked to curves, uneven frontages, or to coal plates, cellar openings, etc.; and repairs are promptly and easily effected after disturbance of the footway. In appearance it is cheerful, yet without glare or reflection from the sun's rays, and the stones are of fairly large size and can be made to break joint evenly. Each flag or slab should be from $2\frac{1}{2}$ in. to 3 in. in thickness, and not more than fourteen pieces should go to make up 100 square feet when laid. Each flag must be evenly and truly bedded on a foundation of dry gravel or brick rubbish, set with blue lias lime mortar, the joints being properly butted together—not feather-edged or undercut—and flushed up with the mortar.

An objection to this description of pavement is its first cost, which is in some districts undoubtedly high as compared to its durability; for instance, whilst in Bradford, Yorkshire flags can be laid at 3s. 6d. per square yard, a similar pavement in Battersea costs 11s. 3d. per square yard. Another objection is the fact of uneven wearing, which pertains to nearly all natural stones, perhaps, with the exception of Caithness stone. It is found that in course of time the softer stones wear down, leaving depressions, in which water lodges, and the stone has to be removed thus causing a patchy footway. With reference to the wear of Yorkshire flags, the author found from

the returns already referred to, that in Harrogate the wear was twenty-five years, whilst in Leicester only six or seven years was stated to be their maximum duration of life. Some flags of this description which were laid in Lombard-street, in the city of London, in 1828, were taken up in 1846, completely worn out, and were estimated to have cost 1s. 3d. per square yard per annum in repairs during that period.

In 1883, Mr. Lovegrove, the surveyor of the Hackney district, reported that flags laid in 1857 had worn from $1\frac{1}{2}$ in. to $1\frac{1}{8}$ in. by 1883, and that those laid in 1864 had worn from $\frac{7}{8}$ in. to 1in.

In Wisbech, flags have lasted for thirty years, and have then been used on edge for crossings. In Kennington, after being down for twenty-five years, they have been taken up and relaid in second-class streets, where they have remained for another twenty years, and have been used on edge for crossings. In Westminster, they are reported as wearing rather rapidly in narrow footways. In the Strand, some Yorkshire flags laid in the year 1861 were subjected to a daily average pedestrian traffic of 46,000 persons, and were thoroughly worn out in the year 1884. These experiences show a very varying result as to the wear of this description of pavement, but this last result gives a wear of $\frac{1}{16}$ in. for every 9,000,000 of pedestrians using the footway.

Other objections, which apply almost equally to other descriptions of natural stones for the paving of footways, may be summarised as follows: liability to tilt if not properly bedded, absorption of moisture, tendency to laminate in frosty weather, and their

weakness to resist fracture when heavy goods are thrown down on them.

With regard to the other natural stones, most of the freestones are of too soft a character to be used outside the districts in which they are quarried, and some of the limestones are very brittle and wear dangerously slippery. Slate wears excessively slippery, so much so that even in Bangor this material is not regarded with favour, and Yorkshire flagging is preferred.

The only natural stone that can compete with Yorkshire flagging as a material with which to pave footways is Caithness stone from Thurso, in Scotland, which possesses qualities which have much to recommend it. From the returns already alluded to, it appears that twenty-three out of the one hundred and thirty-eight towns used this description of stone. Amongst other advantages, it claims to have good appearance; to be much more impervious to moisture than Yorkshire flagging; that it does not wear slippery, nor scale, nor flake; that it dries rapidly after rain and is easily cleansed; that it is very durable in wear; and that frost has no effect on it, besides which it no doubt wears much more evenly than most natural stones, and has considerable tensile strength to resist the shocks of falling goods, etc. In Birmingham, Devonport, South Shields, Sunderland, and in Liverpool, this description of pavement has been in use for many years past, and is still largely used with other descriptions of natural and artificial coverings for footways.

Before closing these remarks on natural stones, the

following suggestions for a specification applicable to any description of flagging for footways may be of some use :

The old flagging (where and when directed) to be taken up, refaced, squared, and relaid. The new flagging to be chisel-dressed to a fair face, true, out of winding, and not less than $\frac{1}{2}$ in. thick*, to be properly squared and not pitched off only, or undercut, but to hold good to the square, to have not more than fourteen pieces to the 100 superficial feet when laid; the joints must be set flush and bedded and pointed with the best blue lias lime mortar.

The bed for the flagging (both old and new), if any is required, to be made with gravel, dry rubbish, or other material to be previously approved by the engineer or his authorised agent, and all surplus earth and rubbish to be carted from the streets as it arises from the works.

The flagging to be properly cut and rebated to receive all area gratings, coal shoots, rain-water troughs, etc.

Any damage done to gas or water service pipes in digging for the flagging, or in any way connected with the work, to be made good by the contractor, as also all and every other damage to windows, wood or glass work; and the contractor will be held responsible for, and will make compensation for, any injury that the public may sustain through the negligence of his workmen or otherwise.

* It is sometimes a rule that Yorkshire flags should be $\frac{1}{2}$ in. thick for every square foot of surface, but they should never be less, in the author's opinion, than 2 in. in thickness.

The whole of the flags to be of the very best quality, from ———, the quarries in the neighbourhood of ——— or in ———, and subject to the approval of the Engineer.

The contractor to provide all lights and proper guards at night, and when old paving is to be taken up the work is to be done under the direction of the Engineer or his authorised agent, and, if considered necessary, the stones are to be removed from the streets to be refaced and squared. No stone to be stacked in the streets.

The flagging to be measured after the work is completed.

The contractor to provide all stone, materials, tools, implements, horse and cart hire, and pay all railway dues, freightages, etc. ; and also to provide all labour of every kind for properly completing the work to the full and entire satisfaction of the Engineer. Payment will be made as the work proceeds, on the certificate of the Engineer.

Natural Asphalte, Compressed and Mastic.

Footways in streets of much pedestrian traffic may with advantage be paved with compressed asphalte, which is laid in a precisely similar manner to that for the carriageways, as has already been described, except that it may be only about 1in. to 1½in. in thickness; consequently it will not be necessary to describe this description of pavement, but a few words upon mastic asphalte are necessary.

In the year 1838 Mr. F. W. Simms speaks of

asphalte mastic from Pymont, near Seyssel, and says: "It may be considered a species of mineral leather"*—a capital description of this tough, hard, durable, and pliant paving material.

The usual method of the preparation of the mastic is as follows: According to the amount of bitumen contained in the natural stone, from 5 to 8 per cent. of refined Trinidad bitumen† is placed in a large cauldron, which is usually provided with agitators driven by steam power; when this is thoroughly melted, the powdered asphalte is added little by little, the heat being raised to between 390 and 480 degrees Fahrenheit, and the mixture kept well stirred and "cooked" for about five hours. It is then turned out into moulds, most companies having a special pattern with a trade mark for this purpose.

The cauldrons generally used contain from one and a half to two tons of mastic.

Some companies in large towns are provided with cauldrons on wheels, commonly called "locomobiles," in which case the grit is mixed with the mastic in the fixed cauldrons, and the whole mass run out into the locomobiles (which are also provided with agitators worked by an endless chain attached to the axle of the wheels), and transported direct to where the work has to be done. This system, though undoubtedly

* *Vide Proceedings of the Institution of Civil Engineers, vol. i., page 6.*

† Trinidad bitumen is best, but it has to be refined before it can be used. This is done by cooking it with shale oil, then straining it and decanting it, which is a troublesome and tedious process, and there is great danger of fraud being practised. Good bitumen can be detected by its elasticity and softness when rolled between the finger and thumb, and also by its smell.

the best, is not practicable except in large towns; the more usual method of laying mastic footways is to send the asphalte cakes to the works, where they are remelted in small round street cauldrons, containing from eight to twelve cakes each, weighing from 40lb. to 50lb., the grit being sometimes added in the fixed cauldrons, sometimes in the street cauldrons, this amount of grit varying from 20 to 60 per cent. according to the nature of the work.

The grit makes the asphalte more difficult to spread, but it lessens the cost and makes a very durable path. The affinity between the asphalte and grit is so great that in breaking a sample the actual pieces of grit will be found broken in half.

The asphalte should be spread from $\frac{1}{2}$ in. to $\frac{7}{8}$ in. in thickness (if compressed, $\frac{1}{2}$ in. is the minimum), and should be brought hot on to the works in covered cauldrons on wheels; the test of its being ready and fit to lay being made by plunging a wooden spatula into it, which should come out without any of the asphalte adhering to it, and also by jets of light smoke darting out of the mixture.

The mastic should be taken from the cauldron with a warmed ladle and put into buckets previously heated, then thrown out on the concrete (which should be perfectly dry) near the spreader, who spreads it skilfully with a wooden stave, spreader, or spatula. The surface should then be floated and dusted over with fine sand, Portland cement, or stone dust.

Dishonest contractors sometimes substitute inferior materials for natural asphalte, such imitations being

made of ground chalk, fireclay, and pitch or gas tar, or ground limestone mixed with bitumen.

A sample of the footway after it is laid should be cut out (this is easily effected by heating the surface with a piece of hot mastic), in order to ascertain that the proper thickness is given, and by applying a light to the sample the smell will readily tell if real asphalte or any inferior material has been used. Stockholm tar or common pitch should not be allowed to be substituted for Trinidad bitumen, or it will spoil the mastic.

Mastic asphalte for footways is excellent in every way. It is almost totally non-absorbent of moisture, has no joints, and is easily cleansed; it requires less cross-fall than other pavements, and it absorbs and does not radiate the heat of the sun, the only objections to it being the necessity for the grit and the temporary unpleasant smoke and smell whilst being laid. It is also necessary to put stone sills round the cellar openings and coal shoots, etc., for the asphalte to butt against, but it makes an invaluable pavement, especially for courts, alleys, backyards, etc., for sanitary and other reasons.

The proportions of asphalte, bitumen, and grit are given as follows by Mr. Delano in his translation of a paper by M. Ernest Chabrier, on the applications of asphalte* :

“One ton of sanded mastic requires 13cwt. of pure block mastic, 2qr. 12lb. of bitumen, 7cwt. of grit or sand washed and dried,” and it takes 2cwt. of coal to

* *Vide Proceedings of the Institution of Civil Engineers*, vol. xliii., page 293.

heat it. He further says that one workman can easily prepare three tons of material in twelve hours.

The following table gives the number of square yards that a ton of prepared Sicilian rock asphalt will spread :

Without grit. Square Yards.	With about 25 per cent. of grit. Square Yards.	Thickness, Inches.
63	80	$\frac{3}{8}$
51	65	$\frac{1}{2}$
32	40	$\frac{3}{4}$
26	33	1
16	20	$1\frac{1}{2}$
$12\frac{1}{2}$	16	2

A skilled workman, properly assisted, can lay 140 to 180 square yards in a day.*

With regard to the price of asphalt mastic footways, this is quite a local question, and is not worth while discussing. The life of a footway thus treated may be reckoned at about fifteen years under ordinary traffic; the concrete will remain untouched, and what is left of the asphalt may be remelted, so that a renewal is not so costly as the first expense.

In no case should the finished asphalt be less than $\frac{1}{2}$ in. in thickness, and it is essential that a good foundation of Portland cement concrete, about 3 in. in thickness, should be provided.

Concrete in Monolith or Slabs.

The use of concrete, as a monolith, and also in slabs, as a paving material for footways, has made

* *Ibid.*, vol. xliii., page 293.

great progress during the last few years, and in nearly every town in the United Kingdom more or less concrete may now be seen as a pavement upon the footways.

When this description of pavement was originally laid in mass with large exposed surfaces, great alterations took place on changes of temperature, and the concrete either cracked or gaped open, or in some cases rose up from its bed into arches and curves. The cure for this has been to lay the concrete in bays of about 6ft. in width, completing each bay alternately, allowing the intermediate one to set before the neighbouring bay is commenced.

Another method is to leave laths or strips of soft wood between the widths of concrete, and subdividing those widths by cutting into the concrete with a trowel before it is quite set, thus splitting up the mass of concrete and giving it plenty of room to expand.

The following may be taken as a fair description of the manner in which monolith concrete footways should be constructed :

Excavate the ground to a depth of about 5in. below the finished level, and upon this lay an even bed about 1in. in thickness of cinders or gravel ; upon this lay a layer of clean hard stone or other suitable material, broken so as to pass through a 3in. ring, well water and roll, filling up inequalities and leaving the surface about 2in. below the finished level of footway. Divide into bays, as described above, with battens of soft wood, and complete each alternate bay by laying upon the stone foundation carefully-

prepared concrete composed of one part Portland cement, two parts coarse clean gravel, or other suitable and procurable material, passed through a lin. screen, and two parts of clean sharp sand, which must be well beaten or rolled into place; and before it is set a finishing coat, lin. in thickness, of a finer and richer concrete is to be added and brought up to the finished surface of the footway, and well trowelled and smoothed into place. This finishing coat may be composed of one part Portland cement to two parts granite chip-pings, Oporto gravel, or other suitable material which will pass through a $\frac{1}{4}$ in. sieve.*

As the work is finished, the battens may be removed and the joints filled with fine sand.

As concrete footways are somewhat more slippery than natural stone, a cross-fall of three-eighths of an inch per foot is sufficient.

In the construction of concrete footways, great care is necessary that the materials should be perfectly clean and well washed, and that none but the best Portland cement, ground very fine, should be used, and that the concrete should be most carefully mixed.

Traffic should be prevented until the concrete is thoroughly set, either by diverting it or by covering the footway with planks for about a fortnight. In hot, dry weather the concrete should be covered with a coating of sand or old cement bags, and kept thoroughly damp.

From a return prepared in 1889 by Mr. MacBrair,

* The selection of suitable materials must depend to a great extent upon locality, but the grit or gravel for the finished surface must not be "rounding," or it will become displaced by the feet of pedestrians.

the City Surveyor of Lincoln,* out of twenty-nine towns from which replies were received, nineteen had footways laid with monolith concrete, which had cost from 1s. 8d. per square yard up to 5s. 6d., and the majority of the surveyors' opinions were in favour of this class of footway.

The objections to this description of pavement for footways are that it cannot be laid during the time that frosty weather may be expected, and it is difficult of repair when broken up for any purpose, in addition to which the traffic has to be diverted whilst it is being laid, which is a serious objection, especially in streets where shops abut on the footways. Consequently concrete slabs are now even more generally used than concrete in monolith, as they overcome all these objections, and have much to recommend them. All these slabs are practically made in a similar manner, with some minor variations; they are usually composed of broken stone, gravel, shingle, sand, etc., mixed with Portland cement and water, placed in moulds and allowed to set hard before being used, the most modern method being to subject them to great pressure in the moulds.

The following method may be taken as a representative description of the process adopted where pressure is not applied: Granite or other stone is broken so as to pass through a $\frac{3}{16}$ in. sieve, and is then carefully washed so as to get rid of the dust, which otherwise interferes with the adherence of the cement to the particles of stone. Only the best Portland cement is used, which

* *Vide Minutes of Proceedings of the Association of Municipal and Sanitary Engineers and Surveyors*, vol. xv., page 189.

complies with a strict specification, and is carefully cooled for at least fourteen days before being used. About one part of cement by measure to three or four parts of broken stone should be used. They are thoroughly incorporated together by machinery or hand labour, water being sparingly added during the mixing, so that the "compo" appears to the eye as almost dry. No more should be mixed than can be at once used. The moulds are made of wood, and may be of various construction; but they are better if lined with metal, as otherwise the concrete will adhere to them. They must necessarily be perfectly true in shape, of sizes which are found to be convenient, their arrises being very clearly defined. Before putting in the concrete, they should be covered with oil or soft soap to further assist in preventing the adhesion of the concrete. The "compo" is placed in the mould in small quantities at a time and carefully punned into all the corners with iron punners, or this is effected by causing a "trembling" motion to the mould, which is placed in a machine for the purpose. When the mould is full the water appears on the surface, and the concrete is "screeded" off to a level and even face. The mould is then removed, and the slab is not taken out for a few days until it is sufficiently set. They are available for paving about three months after manufacture, but the more mature they are the better before they are subjected to wear. In some cases they are placed in baths of either ordinary water or a silicated solution, but the advantages to be gained by this are somewhat doubtful. It is

essential, however, that they should dry slowly and not be subject to the direct rays of the sun; wet straw or mats should be used as a covering during exceptionally hot weather.

Concrete flags of this description are now made under great pressure, whereby the materials become almost homogeneous, and they can be immediately handled, and are fit for use on the footways much sooner than when made in the ordinary manner. The author is now engaged in putting up a concrete slab hydraulic pressure installation for the manufacture of artificial flagging, curbs, etc., to be made with Portland cement and the waste clinker and ashes from a twenty-four-cell refuse destructor, in which process each flag will be subjected to a pressure of about 300 tons, and he anticipates that an excellent paving material will be the result, which can be thus manufactured at about 1s. per square yard of 2½ in. finished thickness, as the value of the matrix proposed to be employed is negligible.

The advantages of concrete slab pavements for footways are that, being of uniform size, the "break joint" is regular and even; the colour is pleasing; they wear evenly, and are, if well made, indifferent to changes of temperature; they are easily cleansed; and, being almost non-absorbent, dry easily and quickly after rain. If evenly and securely bedded they will stand considerable shocks, and when one surface is worn they can be turned over, though, of course, the under face is not so even and smooth as the upper, and the longer they are down the harder does this class of pavement become. Having

thus far exhausted the subject of concrete paving for footways, a few remarks are necessary upon

Bricks or Tiles.

Ordinary bricks were no doubt formerly used for paving footways in some districts because no better material could be procured except at a prohibitive price; eventually hard vitrified stoneware bricks, with a chequered or diamond-pattern surface, were introduced in Staffordshire, and these bricks have been extensively used ever since, principally on account of their cheapness and durability. In West Bromwich, for instance, a pavement of this description only costs about 1s. 9d. per square yard, and has a life of upwards of thirty years; in Derby, these bricks last for twenty years, and can then be used again for other purposes; and generally they have been found excessively durable when thoroughly vitrified, and are especially suitable for use in back streets or narrow footways in the districts in which they are manufactured. They have, however, a multiplicity of joints, which makes such a pavement difficult to cleanse, and the pavement cannot therefore be considered a sanitary one; they are difficult to bed level, unless laid upon a foundation of concrete, which adds largely to the cost; they wear very slippery and unevenly, and unless the quality is of the best, the skin is soon rubbed off, showing a red interior, which wears as rapidly as an ordinary building brick. A thoroughly satisfactory pavement of this material is not easily obtainable; the appearance of the bricks is against

them, as they are of sombre colour; and a brick pavement always feels "harsh" to the feet.

In the United States, however, bricks and tiles are largely used, and an authority upon street pavements in speaking of this description of covering for footways says: "Bricks of suitable quality well and carefully laid on a concrete foundation make an excellent footway pavement for residential and suburban streets of large cities, and also for the main streets of smaller towns. . . . The bricks should be laid in parallel rows on their edges, with their length at right angles to the axis of the path. They should be set in cement mortar, and the joints filled flush and made as close as possible."*

Another American writer on this subject says: "Brick footway pavements have been extensively used for many years, and form, when well constructed, a very durable and satisfactory sidewalk. As commonly constructed, they consist of ordinary hard-burned bricks laid flat upon a layer of sand over the earth bed. . . . In constructing such a pavement the sand layer should be well compacted by rolling or ramming before setting the bricks, which should also be rammed to a firm and even bearing. . . . In Washington, a layer of gravel 4in. thick and well compacted is used with a layer of sand of the same thickness upon it to receive the surface. In forming the pavements the bricks are laid flat and as close as possible. The joints are filled with sand usually by coating the surface with a layer of sand before ram-

* "A Treatise on Highway Construction," by Austin T. Byrne. John Wiley and Sons, New York.

ming, and after completion a second coating, which is allowed to remain a few days after admitting the trowel to it.”*

This seems a more economical plan than that described by Mr. Byrne, but at best this class of pavement cannot be recommended, and is not likely to be extensively used in this country except under very exceptional circumstances.

Before concluding this little work upon the construction of paved carriageways and footways, a few remarks are necessary upon

Various Compositions.

Most of the materials with which footways may be paved have already been dealt with, but a few still remain, of which a short description may prove useful.

The best known of these is artificial asphalte, or tar pavement, which was introduced early in this century owing to the cost of natural rock asphalte, and the knowledge that it is composed of two very simple ingredients, limestone and bitumen, one of the first being a compound of the following ingredients:

Material.	Proportions.
Waste products of tar oil	50
Caustic lime	20
Pitch	200
Sawdust	30
Iron slag, grit, or chalk	700
Total.....	1,000

* “A Textbook on Roads and Pavements,” by Fred. P. Spalding. John Wiley and Sons, New York.

These materials were simply mixed together, spread upon the footway, and rolled in layers of suitable thicknesses, but the result, as may be imagined, was not very satisfactory.

Another mixture, known as "Lord Stanhope's composition," was laid in London as early as the year 1840, and was made and used in the following manner: 30 gallons of Stockholm tar mixed with 20 bushels of chalk and 10 bushels of clean sharp sand were boiled in cauldrons and spread to the thickness required whilst hot.

A more modern method for the preparation of tar pavement, and one which is still followed in many districts of this country, may be described in detail as follows: Either gravel or stone chippings must be carefully screened through sieves of $1\frac{1}{4}$ in., $\frac{3}{4}$ in., $\frac{1}{2}$ in., and $\frac{1}{4}$ in. gauge, and then heated on iron plates with fires burning underneath. The gravel or chippings having been thoroughly dried and heated, the following ingredients are mixed together, boiled in iron cauldrons, and added whilst hot: 12 gallons of tar, $\frac{1}{2}$ cwt. of pitch, and two gallons of creosote to about one ton of the screened materials. The composition when added to the gravel or chippings should spread easily and thoroughly over every particle of the stone. This now becomes tar concrete, and can be laid in layers, the largest size gravel at the bottom, and so on up to the smallest size for the top layer, each layer as it is laid being well rolled with an iron roller of about 10cwt.

In order to secure success with this description of pavement it is well to observe the following condi-

tions: The stone chippings, or gravel, must be thoroughly heated so as to ensure perfect dryness, as then the composition will adhere firmly. It is better to keep the tarred materials a month or two before use, so that they may be thoroughly soaked by the composition. Broken Kentish ragstone or limestone chippings make the best tar pavements, as too hard a material causes a "bumpy" path. The laying should, if possible, be carried out in the Spring, or Winter, if dry, as a hot sun draws the composition away from the stone on to the surface of the footway. The foundation of the footway must be dry, as water seriously affects the tar concrete. When the last layer of the footway has been completed it must be dusted over with fine grit or stone dust, and this facing, accompanied by a thin "painting" with tar, should be repeated at least once every other year.

Referring again to the returns to which the author has already alluded, it appears that at Banbury the cost of tar pavement was only 9d. a square yard, whilst at Hereford it was 3s. In Bath, the cost was 1s. 9d., and the footways lasted in good repair for twenty years; whilst in Burnley their life was only five years. In Darlington, they lasted for ten years, and were then re-topped at a cost of 3d. per square yard, their original price having been 2s. per square yard. In Doncaster, where the cost was 1s. 8d. per square yard, the footways wore from twenty to thirty years. In Harwich, the cost was 1s. 4d., and the footways lasted ten to twelve years, a coating of hot tar and sharp grit being put on the surface every year. In Ipswich the life was thirteen years; and in

Peterborough, where the cost was only 1s. 3d. per square yard, the life was from fifteen to twenty years. In Scarborough the cost was 1s., and the life ten to fifteen years; and in Windsor, the cost was 2s., and the life twenty years. In Streatham, some footways laid down in the year 1870 remained perfectly sound and good at the end of the year 1885.

The disadvantages of tar pavement are that it is dark in colour unless a very light-coloured stone chipping is used; it is apt to wear gritty or bumpy; it is rather difficult to repair, and in very hot weather it sometimes becomes rather sticky or soft. Tar pavement must only be reckoned as a substitute for ordinary gravelled footpaths; it must not be compared with paved or asphalted footways; and in no case in the Returns to which allusion has been made is tar pavement the only material used on the footways.

In order to show how popular this description of material is, it appears from these Returns that sixty-four towns successfully employed it for suburban footways, though, of course, it is unsuitable for the more urban districts, or where there is much continuous pedestrian traffic upon the footways.

Compressed cork and bitumen tiles, about 2in. in thickness, of similar composition to those already described for carriageways, have been tried with some success, and asphalte blocks about 8in. square and 2in. thick are also sometimes laid upon footways; in both cases a concrete foundation of about 3in. in thickness being necessary.

Gravel or cinder footways will not be dealt with

as a description of them has no place in connection with paved footways.

In conclusion, the author trusts that this little book may add something of value to the literature which now exists upon the subjects he has treated.





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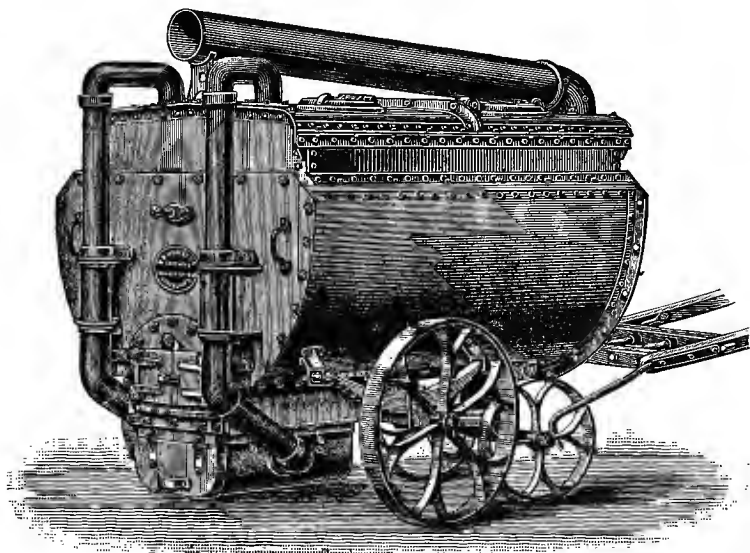
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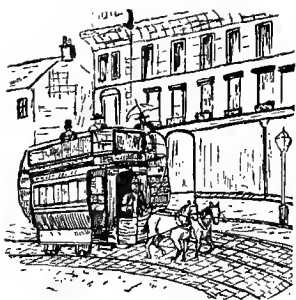
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